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DISEASES OF FLOWERS AND OTHER ORNAMENTALS

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CONTENTS

DISEASES OF FLOWERS AND OTHER ORNAMENTALS

RALPH E. SMITH[1]

INTRODUCTION

INCLUDED IN THIS CIRCULAR are diseases of flowers, shrubs, flowering and shade trees, and lawns. Similar circulars on diseases of fruits and nuts, diseases of truck crops, and diseases of field crops, are being issued. The main purpose of these four circulars[2] is to give a brief, popular account of the nature of and control methods for the important plant diseases in California, as far as such information is available; a further purpose is to mention, under each plant, all the specific diseases which have been observed on it in this state so that the work may serve as a check list of California plant diseases. Mere records of parasitic fungi on various hosts, however, are not included. Certain diseases of much importance in other parts of the United States which do *not* occur or flourish in California are also mentioned to aid those who want to obtain disease-free seed or plants, or to help in identifying new diseases which may appear in this state.

Diseases and failures of plants are due to a great variety of causes. For this reason the problem of understanding and controlling them is often a complicated one. Some diseases are caused by definite parasites which can be fought with sprays and other devices similar to those used in the struggle with insects. Other troubles arise from the existence of conditions which are unfavorable to the plant in some way but which may be difficult to determine or change. In the latter respect, it should be remembered that all kinds of plants naturally do not thrive equally well in all places or under the same conditions; some do better under certain circumstances than others and consequently can be more easily brought to perfection in any given locality. When conditions are too difficult for a particular kind of plant, the experienced grower may give up trying to fight adverse conditions and change to some other kind of plant that is easier to grow in his particular place.

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[2] These circulars supersede portions of Circular 265, *Plant Disease and Pest Control*, by W. T. Horne, E. O. Essig, and W. B. Herms. The portions dealing with insect pests have been superseded by Extension Circular 87, *Insect and Other Pests Attacking Agricultural Crops*, by E. O. Essig and W. M. Hoskins. The other members of the present series are Extension Circular 119, *Diseases of Truck Crops;* Extension Circular 120, *Diseases of Fruits and Nuts;* and Extension Circular 121, *Diseases of Field Crops.*

Plant diseases may be divided into two types, parasitic and nonparasitic. In the former group are included fungus, bacterial, insect, and nematode attacks.

Fungi are microscopic organisms that cause diseases like mildews, rusts, and smuts, as well as molds and rots. In most cases their threadlike filaments, invisible to the eye, grow inside the plant (on the surface in the case of powdery mildews) and weaken or injure it by absorbing food and destroying the tissues. Most fungi spread and reproduce themselves by means of bodies called "spores," which in typical cases like the molds, mildews (fig. 28, p. 65), smuts, and rusts (fig. 3, p. 15) are visible in mass to the eye as a dusty powder. These spores may blow in the air or be carried on the bodies of insects, living plants, bulbs, or seeds, or by other modes of transportation.

Bacteria are microörganisms even smaller than fungi and are only visible in certain cases as a slimy exudate. They are spread in a manner similar to fungi and are of the same general nature as the bacteria or germs which cause human and animal diseases.

Nematodes (eelworms) are organisms of the animal kingdom whose attacks are included here in a number of cases because these creatures (fig. 15, p. 44) are so small as to be practically invisible to the eye, and their effects upon plants are similar to many others which are listed as diseases. A few insect effects are also included for similar reasons, although in such cases descriptions of the insects themselves will be found in Extension Circular 87, to which reference is made in each case.

Nonparasitic diseases are mainly the effects of soil and climatic conditions such as moisture, temperature, and chemical substances. Direct, obvious, or easily diagnosed injuries like those caused by frost, wind, excess water, drought, or chemical salts (alkali) in most cases are not described as diseases under specific hosts.

Viruses are foreign substances which invade, spread, and increase in the bodies of plants, and often cause specific diseases and great injury. Many human and animal diseases (measles, smallpox, rabies, foot-and-mouth disease) are of a similar nature. The virus itself is invisible even under the strongest microscope; and, while in many respects it behaves like a parasitic living organism, it has other characteristics which make it seem a nonliving chemical substance. Most plant-virus diseases are spread by aphids, thrips, or leafhoppers which feed on affected plants and then on healthy ones.

If there is difficulty in diagnosing a disease, help can be obtained from the county farm advisor or specimens may be sent to the Division of Plant Pathology, University of California College of Agriculture, Berk-

eley. In case of plant diseases or troubles in which no insects can be found, an effort should be made to select specimens which seem to be typical of the disease. If it is necessary to include fresh leaves, stems, roots, flowers, or fruit, these should be packed in such a way that they will not dry out. Fresh plant material can be kept in good condition in waxed paper without adding any moisture, or, if it seems better, the samples may be wrapped in moist newspaper and this again enclosed in a tight covering. A screw-top mailing tube makes a good container for fresh vegetation without adding any moisture. Plant-disease samples should be addressed to the *Division of Plant Pathology, College of Agriculture, Berkeley*. Requests for information about insects should be addressed to the *Division of Entomology, College of Agriculture, Berkeley*. In parts of the state where it is more convenient, information may be obtained from the same divisions at the College of Agriculture, Davis, or at the College of Agriculture, University of California at Los Angeles. A letter fully describing the trouble should always be written and mailed to the same address at the time the specimens are sent.

The California Agricultural Experiment Station has issued many bulletins and circulars which discuss certain individual plant diseases much more fully than can be done in this publication. There are also bulletins upon insect pests and upon culture of important crops, including their principal pests and diseases. A list of the available Experiment Station publications, which are sent free on request, may be obtained by addressing the *Publications Office, College of Agriculture, Berkeley*. Consultations, publications, and other services of the College of Agriculture are free as far as possible.

Other bulletins upon plant diseases and insects, as well as on numerous other subjects, are published by the experiment stations of other states and by the United States Department of Agriculture, Washington, D. C. Many of these may be obtained free or for a small charge or may be seen at the offices of the local county farm advisors.

References are given throughout this circular to useful publications on various topics. Bulletins which are out of print may be consulted in public libraries. There are also valuable references of general interest in California.[3]

[3] Essig, E. O. Insects of western North America. 1025 p. 766 figs. The Macmillan Company, New York, N. Y. 1926.

Heald, F. D. Manual of plant diseases. 2nd ed. *xii* + 953 p. 59 figs. McGraw-Hill Book Co., New York, N. Y. 1933.

Heald, F. D. Introduction to plant pathology. *xi* + 579 p. 200 figs. McGraw-Hill Book Co., New York, N. Y. 1937.

Owens, C. E. Principles of plant pathology. *v* + 629 p. 222 figs. John Wiley and Sons, New York, N. Y. 1928.

DISEASES OF SPECIFIC PLANTS

ACACIA

Chlorosis.—Acacias are affected by lime-induced chlorosis in certain areas where the soil contains considerable amounts of lime. This causes a bright-yellow color of the foliage and stunting of the trees. See p. 76.

AFRICAN VIOLET, SAINTPAULIA IONANTHA

Chlorotic Ring Spot.—The symptoms of this disease consist of chlorotic spots which have dark-green edges with light-green to yellow centers. These spots, which usually occur on all leaves of an affected plant, are circular to irregular in shape, vary from ¼ to 1 inch in diameter, and are irregularly distributed over the surface of the leaf blades. They give the diseased plant a distinctly chlorotic or yellowed appearance. The exact nature and cause of the trouble has not been definitely determined. Attempts to transmit the disease by juice inoculations to healthy African violet plants have been unsuccessful. The amount of light under which plants are grown seems to be the most important factor in the development of ring spot. When plants are exposed to ordinary greenhouse light, the disease is of common occurrence. But if the light is reduced by means of a heavy application of whitewash on the greenhouse glass or by suspending a single layer of cheesecloth above the plants on the greenhouse benches, normal, healthy leaves develop. If diseased plants are placed under similar conditions, all new leaves develop normally.

Chlorotic ring spot may be entirely cured by shading the plants.

ANEMONE

Blight.—The leaves of affected plants of *Anemone coronaria* turn to a dark, bronzy color and gradually wither and die, beginning with the outer ones. The corms and roots remain sound until most of the leaves are dead, but may finally die. The flower stalks are shortened and the flowers stunted and aborted. Indications of this disease may be found in first-year plantings from seed, but it becomes more pronounced in plants grown from corms, in their second year. The cause is unknown. All plants which show the above symptoms should be destroyed as soon as they can be detected.

Mosaic.—A virus disease of this type has been reported on *Anemone japonica* in California, but is not serious. A very similar effect on anemone plants caused by mealybug is often observed.

Rust.—On the leaves of the cultivated anemone (*Anemone coronaria*), an interesting fungus—*Tranzschelia pruni-spinosae*—is occasionally found in California. This is the spring form, or aecial stage, of the well-

known rust which later in the season attacks the prune, plum, peach, apricot, and almond. On the anemone, the plants are stunted and sometimes fail to bloom, the leaves become thickened, and little pitted cups in which the spores are developed form on the undersides of the leaves. The stage on anemone is probably not necessary to the life history of the prune rust in California, since the fungus is able to reproduce itself by summer (uredo) spores which are produced the year round on overwintering leaves, twigs, and similar susceptible tissues of the fruit-tree hosts. Affected anemone plants should be destroyed.

ANTIRRHINUM

See "Snapdragon" (p. 68)

APRICOT, FLOWERING

See "Prunus, Ornamental and Native" (p. 57)

ASTER

Root Rot.—The plants attacked by this disease wilt and die on account of a rotting of the main root and lower stem. This is caused by a fungus, *Phytophthora cryptogea,* and like similar fungus diseases of other plants, is favored by excessive soil moisture. To prevent it, avoid overwatering or planting in poorly drained spots.

Rust.—In aster rust, the leaves are more or less blighted and killed, and on the undersides are seen orange-colored, powdery pustules of fungus spores. This is a true rust, *Coleosporium solidaginis.* This disease is not usually serious enough to need treatment, but if necessary, the foliage may be dusted with sulfur when the disease first appears.

Spotted Wilt.—The first symptoms of spotted wilt in aster plants are seen in a discoloration and dying of the green surface tissue in streaks on the stems or circular patches on the leaves. The plants often take on a bushy form at the base by pushing out of the lower side branches. The young leaves show mosaic mottling. The original cause is a virus, but when the tops of mature plants die, the roots and the crown or lower part of the stem become rotted by *Botrytis* or other common molds, especially on heavy soil with plenty of water. The final effect of this disease somewhat resembles that of fusarium wilt, but the early stages are very different. Fusarium wilt starts with a discoloration of the inner woody tissue of the root and lower stem, and the cortex or bark is the last part to be affected. Spotted wilt of aster is identical with the disease of the same name which affects tomato and many other kinds of plants. It is spread by thrips. See page 90.

Affected plants should be rogued out and destroyed as soon as detected.

Wilt.—The plants wilt, wither, and die, either as seedlings or after reaching considerable size. The woody tissues of the root and lower part of the stem show discoloration and decay. This disease is caused by a soil fungus, *Fusarium conglutinans* var. *callistephi,* which, like other *Fusarium* species, gradually increases year by year in a given piece of ground until asters cannot be grown there.

Varieties of asters resistant to wilt have been developed, and seed is now available on the market. Such varieties are designated by seedsmen as "wilt-resistant" asters. They are not resistant to spotted wilt. In growing aster plants, precautions against damping-off should be taken in the seedbed and flats. See page 80.

Yellows, California Aster Yellows.—The shoots and terminal leaves show a peculiar, yellow, "spindling" growth ; the flowers or parts of them are deformed and have a greenish-yellow color, regardless of the normal shade. The plants are stunted and weakened, the flowers ruined, and little seed produced. This is one of the virus diseases and is spread by a small leafhopper, *Macrosteles divisus,* and possibly by other species. The same disease attacks many other plants, including lettuce, celery, parsley, carrots, zinnia, and marigold.

Yellows-affected plants should be destroyed as soon as found because they harbor the virus. It is possible to prevent yellows in asters by planting them in cheesecloth or wire-screen cages to keep out leafhoppers. Cloth with 22 threads or screen with 18 wires to the inch should be used.

AZALEA

Chlorosis, Stunting.—Azaleas, like heathers and rhododendrons, prefer a slightly acid, well-drained, somewhat sandy soil containing plenty of organic matter. If the soil is not favorable in these respects the plants are likely to develop sickly, yellow foliage and make very little growth. If it is desired to grow these plants where the soil is not suitable it may be removed before planting to a depth of 2 feet or more and replaced with a mixture of leaf mold and sandy loam. Established plants may be treated by spading into the soil annual applications of sulfur, ammonium sulfate, or aluminum sulfate, together with leaf mold, well-rotted manure, or peat. Surface mulching with pine needles, leaves, or leaf mold is also beneficial.

Leaf Curl.—The leaves are thickened, swollen, and at first pinkish in color, but later are covered with a white bloom of fungus spores (*Exobasidium vaccinii*) as in peach leaf curl. No treatment has been tried.

Leaf Spot.—Affected leaves show dead spots caused by a fungus, a species of *Septoria.* The disease is not important.

BALM OF GILEAD, POPULUS CANDICANS

See "Cottonwood and Poplar" (p. 18)

BARBERRY

Rust.—A true rust, *Puccinia mirabilissima,* sometimes attacks the so-called "Oregon grape," *Mahonia* (*Berberis*) *nervosa,* and causes dead spots on the leaves, with numerous pustules of dark-red rust spores on the underside.

Wheat Rust.—The common barberry bush, which is important as the host of one stage of the wheat-rust fungus, *Puccinia graminis,* does not occur in California. The rust is able to maintain itself here throughout the year, however, on growing cereals and grasses.

BACHELOR'S BUTTON

See "Cornflower, Bachelor's Button, or Centaurea" (p. 16)

BEGONIA

Bacterial Leaf Spot.—Characteristic of this disease are roundish dead spots which appear, scattered over the surface of the leaves. These spots are brown with yellow, translucent margins. Badly affected leaves fall from the plant. This bacterial disease is caused by *Phytomonas flavozonatum,* but high humidity and temperature, crowding of plants, and poor ventilation favor it. Spotted leaves should be removed and destroyed. Proper spacing and ventilation will usually keep the disease in check.

Leaf Nematode Blight.—Large, dead areas, definitely margined by the veins, develop on affected leaves. The cause of this disease is *Aphelenchoides fragariae,* a nematode worm (p. 82), invisible to the eye, which lives in the tissues of the leaf. This is a similar but different worm from the one which attacks the roots. Chrysanthemums, coleus, gloxinia, ferns, and many other plants are sometimes similarly affected.

Affected plants and trash should be destroyed and not allowed to come into contact with fresh stock. Soil in which diseased plants have grown should be discarded and the pots dipped in boiling water.

Root-Knot Nematode.—Small swellings or galls develop on roots attacked by this nematode, and the plants, if badly affected, become stunted. This is the garden nematode, *Heterodera marioni,* which attacks many hosts (p. 82). Greenhouse or nursery soil is likely to become infested which causes much trouble to the propagator.

All infested plants and material should be destroyed. Infested soil must be discarded or treated with steam (p. 80).

Spotted Wilt.—See page 90.

BELAMCANDA

Leaf Spot.—Dead spots caused by a fungus, *Heterosporium gracile,* appear on the leaves. To control the disease, remove and burn all badly affected leaves.

BULBS

See individual hosts, "Freesia," "Gladiolus," "Narcissus," etc.

CALENDULA

Powdery Mildew.—The leaves become covered with a grayish white growth of the fungus *Erysiphe cichoracearum.* Dusting with powdered sulfur is the usual method of control.

Smut.—This disease, which is common in commercial plantings near

Fig. 1.—Calendula leaf smut.

San Francisco, has been observed for a number of years but does not seem to cause much damage. Small, round, whitish, blisterlike spots appear upon the surface of the leaves (fig. 1). These contain the spores of the fungus *Entyloma calendulae.* Affected plants or leaves should be destroyed if the trouble seems serious.

CALLA

Chalk Rot.—Growers distinguish by this name a dry rot of the corm which leaves the tissue in a white, starchlike, or chalky condition. The cause is unknown, but all affected corms should be discarded. Apparently healthy corms may be dipped as recommended for root rot.

Leaf Spot.—Large, dead, dark-colored, unsightly patches are caused on the leaves and petioles of growing plants by the fungus *Phyllosticta Richardiae.* To control, avoid overwatering the foliage. Callas which are

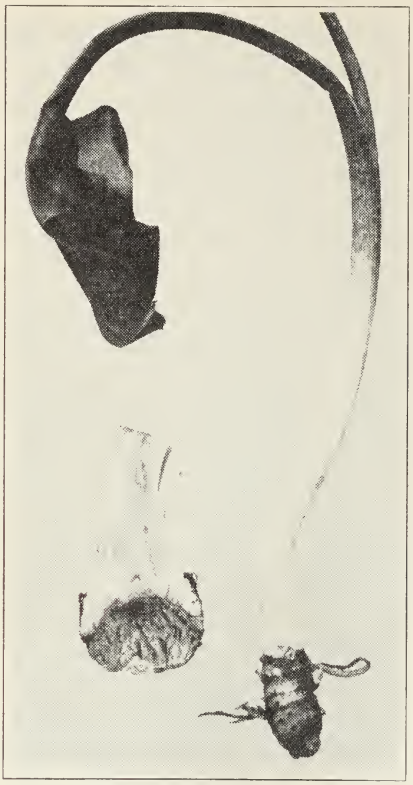

Fig. 2.—Calla root rot.

grown in rich soil with liberal overhead irrigation are apt to develop a dense mass of succulent foliage which is very susceptible to disease.

Root Rot.—Affected plants are much stunted, with yellow, drooping leaves and poor growth. The fungus *Phytophthora Richardiae,* attacks the feeder roots, which rot from the tips back to the corms with a water-soaked appearance, and finally become hollow tubes. In bad cases the corms are entirely bare of lateral roots (fig. 2), for the latter rot off as fast as they are formed. Sometimes, in growing plants, the rot runs back into the corms from the bases of the side roots, but usually not extensively. In the corms the rot is dry and spongy and not of a slimy, soft type. Corms which have been affected in the field may develop the same dry rot in storage, and serious losses to bulb growers occur in this way.

Infested soil should be avoided for planting callas but may be used

for any other crop. The disease has a decided relation to drainage, being much worse in wet land. For growing calla corms, soil should be carefully leveled and provided with good surface drainage so that there will be no low spots or standing water on the beds.

Corms for planting should be obtained from disease-free stock and may be dipped as an extra precaution. For this purpose soak the corms for 1 hour just before planting in a solution of formalin 1–50 (p. 100) (1 pound commercial formalin to 6 gallons of water) or corrosive sublimate 1-1,000 (p. 100) (1 ounce to 7¾ gallons of water). Where this disease is troublesome, the planting stock should be carefully selected and corms which show any signs of rot, either at the crown or side-root scars, should be rejected. In curing and storing corms from fields which have shown the disease, all that are visibly affected should be thrown out. There is no treatment which will keep the rot from developing in corms which are slightly affected.

Soft Rot.—Where drainage is poor or too much water has been used, the corms of growing plants in the field are often attacked by a soft, slimy, bacterial rot which may kill the plants. This sometimes happens also in high spots in the field where plants have been weakened by drought. The causal organism is *Erwinia carotovora* or *E. aroidea*. This disease should not be troublesome where the land is properly leveled and irrigated.

Spotted Wilt.—See page 90.

CAMELLIA

Bud Blight, Blast.—The tips of the flower buds and edges of the young petals sometimes turn brown and decay before opening. This trouble appears to be nonparasitic; it may be started by the attacks of thrips but is aggravated by heat and sunburn.

As preventive measures, water the roots freely but avoid wetting the buds in hot weather. Plants in partial shade are less affected. To control thrips, Extension Circular 87 recommends spraying with a highly refined commercial oil emulsion spray, to which is added nicotine sulfate (Black Leaf 40), at the rate of 2 gallons of oil emulsion and 1 pint of Black Leaf 40 to 100 gallons of water, or 2½ ounces of oil emulsion and 1 teaspoonful of Black Leaf 40 to 1 gallon.

Scab.—Rough, corky scabs grow out on the undersides of the leaves and cause them to fall prematurely, which weakens the plant. The cause is unknown. To control, pick off and burn all affected leaves. Do not propagate from affected plants or keep them in the vicinity of healthy ones.

CAMPHOR TREE

Oak-Root-Fungus Disease, Armillaria Root Rot.—The disease caused by *Armillaria mellea* (p. 84) has been reported on this host in one case.

CARNATION

Damping-off.—This is a common cutting-bed trouble, where the plants rot off at the surface of the sand. It is the same disease as damping-off in seedbeds and is usually brought on by overwatering. Some of the same fungi (*Fusarium, Rhizoctonia*) cause stem rot of older plants. Avoid overwatering and use the methods recommended under "Damping-off" (p. 80).

Leaf Spot.—Symptoms are dead, light-colored spots with purple margins on the leaves, stems, and calyxes. In severe cases the fungus, *Heterosporium echinulatum,* becomes visible as a dark mold. Two other fungi, *Alternaria dianthi* and *Septoria dianthi,* also cause leaf spotting. To prevent leaf spot, destroy badly affected leaves or plants and keep foliage dry. Discard susceptible varieties if possible.

Rust.—Dark-brown, dusty, rust pustules sometimes break out in spots on the leaves. This fungus disease, caused by *Uromyces caryophyllinus,* is ruinous to some varieties, but others are much less susceptible.

The same treatment may be used as for leaf spot. Spraying is not very satisfactory. Dusting with dry sulfur may help.

Wet Stem Rot.—A common soil fungus, *Corticium vagum,* sometimes attacks the stems of the plants and causes a soft rot. It is usually favored by overwatering. The best methods of control are to dry the soil as much as possible and destroy affected plants. Contaminated greenhouse soil may have to be removed or sterilized or chemically treated (p. 80).

Wilt.—Affected plants wilt, wither, and die. Two distinct fungus diseases are probably involved here, caused by different species of *Fusarium.* One attacks the woody tissue of the stem while the other causes a soft rot of the lower stem and root. To control, remove and burn affected plants promptly. Take cuttings from healthy plants. Use clean, fresh sand and soil for cuttings and growing plants. Change or sterilize soil if necessary (p. 80).

CEDAR, INCENSE

See "Incense Cedar" (p. 35)

CHERRY, ORNAMENTAL AND NATIVE

See "Prunus, Ornamental and Native" (p. 57)

CHESTNUT

Blight.—This disease recently appeared in California on cultivated chestnuts (there are no native hosts), but all affected trees have been destroyed as fast as discovered. The fungus, *Endothia parasitica,* attacks the bark of smooth, young shoots, where discolored, elongated, dead areas develop. On older parts, the diseased bark cracks and forms rough cankers. These cankers girdle the stems so that branches, young shoots, or whole trees wither and die. Spore pustules break out through the bark. Trees whose tops have been killed usually sprout up from below, and these new sprouts may be successively attacked and killed. This disease, which was introduced from the Orient, has almost exterminated the native chestnut in the Atlantic states.

Trees affected or suspected of being affected with this disease should be reported at once to the County Agricultural Commissioner or State Department of Agriculture, who will attend to their destruction. It is illegal to bring chestnut trees into California.

CHOKE CHERRY, PRUNUS DEMISSA

See "Prunus, Ornamental and Native" (p. 57)

CHRISTMAS BERRY

See "Photinia, Heteromeles, or Toyon" (p. 52)

CHRYSANTHEMUM

Leaf Blight.—Affected leaves turn yellow, wither, and fall, progressing from the lower ones upward. Leaf blight is due to various causes but is usually most serious where plants are closely crowded, poorly watered, and attacked by red spider. The trouble may be largely prevented by avoiding these conditions.

Leaf Nematode Blight.—See under "Begonia" (p. 9).

Powdery Mildew.—In this disease, the leaves become covered with a white mildew fungus, *Erysiphe cichoracearum.* To control, dust with sulfur or spray with 1 per cent lime-sulfur solution (p. 101) or wettable sulfur (p. 101). Nicotine for aphids may be added to these sprays.

Rust.—This disease is not often serious on chrysanthemums in California as usually grown either in the open or under cloth but occasionally flares up on certain varieties. It is a true rust; it blights the leaves, which are covered with pustules of dark-red spores of the fungus *Puccinia chrysanthemi* (fig. 3).

The recommended control measures are to avoid growing varieties

which seem very susceptible in certain localities, to dust with sulfur at the first sign of rust, and to destroy affected plants.

Verticillium Wilt, Verticilliosis.—The leaves of plants infected with this disease fade and wither, beginning with the lower ones on the main stalk, and finally the whole stem dies. Some of the plants may be almost in full bloom when this happens. In many cases the small leaves and

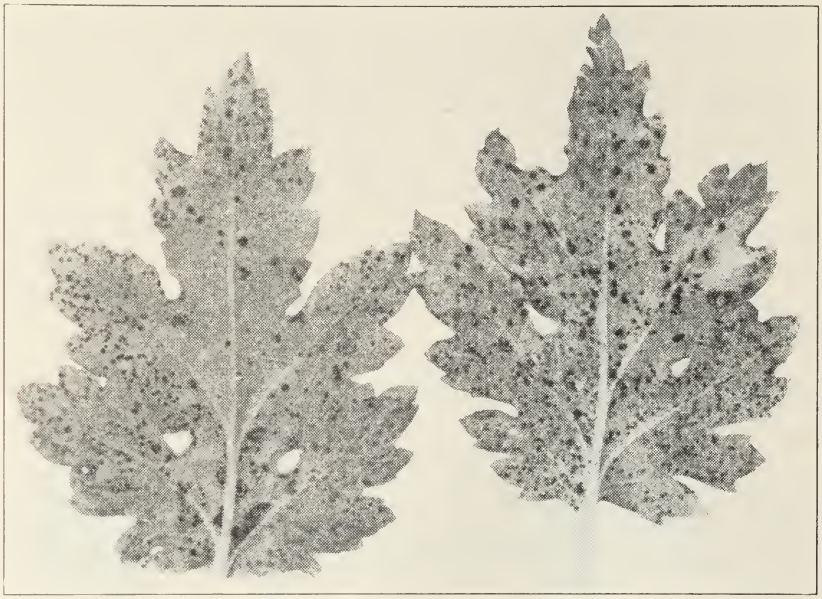

Fig. 3.—Chrysanthemum rust.

shoots at the base of the plant do not die, consequently there is danger that some of these may be used for propagation after the dead flower stalk has been cut off. This disease is due to the same fungus—*Verticillium albo-atrum*—that causes similar troubles in tomatoes, cotton, and many other plants (see p. 92).

Great care should be taken not to plant offshoots from diseased plants. Healthy plants should be selected for propagation before flowers are cut. Affected soil should not be used again for chrysanthemums for several years. Land which has recently been in tomatoes or some of the other hosts of this disease may also be infested with the fungus. Some varieties of chrysanthemum are resistant to this disease.[3a]

[3a] For further information, see: Tilford, P. E., H. A. Runnels, and C. Miller. The verticillium disease of chrysanthemums and its control. Chrysanthemum Society of America, Bul., vol. 7, no. 1, p. 9–16. 1939.

CINERARIA

Leaf Blight, Leaf Miner.—This insect effect, caused by the leaf miner, *Phytomyza chrysanthemi,* is often mistaken for a fungus disease. The leaves are badly disfigured with whitish, dead lines where the maggots have burrowed through the tissue. For control of the insect, spray with a 1-600 dilution of 40 per cent nicotine sulfate (Black Leaf 40). See Extension Circular 87.

CLARKIA

Downy Mildew.—Affected leaves are blighted with a delicate fungus growth of a species of *Peronospora,* visible on the underside; the trouble is not serious.

COCKSCOMB, CELOSIA

Root Rot.—This fungus disease, caused by a species of *Phytophthora,* has been observed only in greenhouses. The plant wilts and dies from a rotting at the crown and base of the stem. To control, avoid overwatering and the use of infested soil.

COLEUS

Leaf Nematode Blight.—See under "Begonia" (p. 9).

COLUMBINE

Powdery Mildew.—Affected leaves are covered with a typical mildew fungus growth, *Erysiphe polygoni,* at first white but later becoming darker-colored. This may be controlled by dusting with finely pulverized sulfur.

CORNFLOWER, BACHELOR'S BUTTON, OR CENTAUREA

Powdery Mildew.—A white mildew, *Erysiphe cichoracearum,* sometimes covers the foliage and flower buds and blights and distorts the growth. The recommended control is to dust with sulfur when the fungus is first seen.

Rust.—In this fungus disease, red or dark-colored spore pustules of *Puccinia cyani* break out on the foliage. Dusting with sulfur as for mildew will help to control this.

COSMOS

Stem Blight.—In this disease, a brown canker or dead spot develops on the stem of mature plants and may extend for several inches in length or girdle the stem. Small, black, spore pustules of the fungus, *Phomopsis Stewartii,* appear on the surface of the dead tissue. The plant above the canker withers and dies. No control is known except to remove diseased plants.

COTONEASTER

Fire Blight, Blight.—In cotoneaster plants attacked by this bacterial disease, blossom clusters, shoots and branches wilt and die as in the same

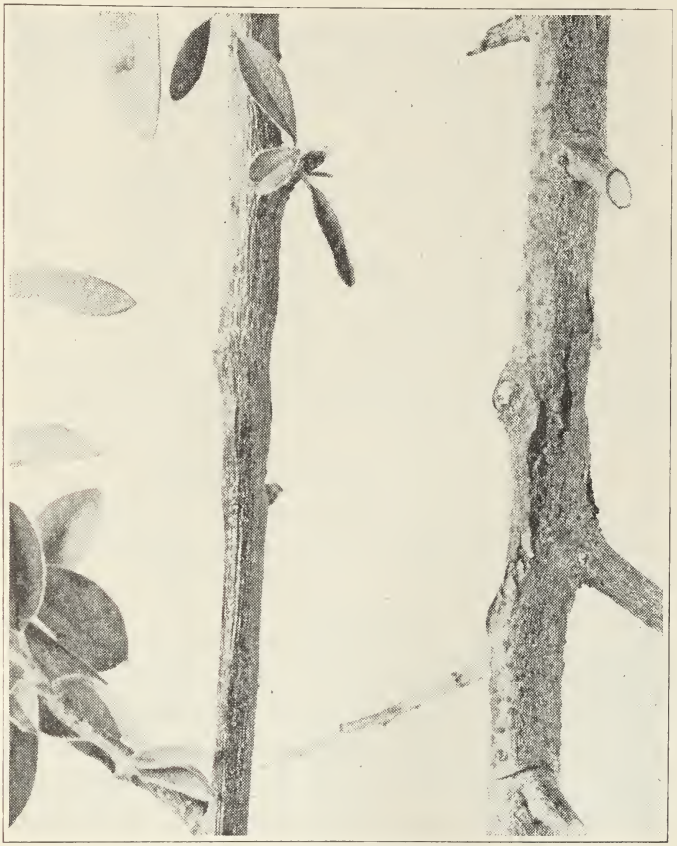

Fig. 4.—Cotoneaster stems with blight cankers.

disease on pear and apple. Cankers are formed on the stems (fig. 4). The cause is *Erwinia amylovora.*[4]

Diseased parts should be cut off, the cuts being made several inches below the affected portion. Cutting tools should frequently be swabbed with a rag saturated with corrosive sublimate 1-1,000 (p. 100). Several species of cotoneaster are highly resistant or immune to blight, such as forms of *Cotoneaster buxifolia, C. Franchettii, C. glaucophylla, C. Harroviana,* and *C. microphylla.* Some of these may be substituted for the

[4] For more complete information see: Thomas, H. E., and P. A. Ark. Fire blight of pears and related fruits. California Agr. Exp. Sta. Bul. 586:1–43. 7 figs. 1934.

susceptible sorts like *C. Dammeri* var. *radicans, C. pannosa,* and *C. salicifolia.* Because of the tendency of some species (for instance, *C. salicifolia*) to hybridize freely, it is desirable to use rooted cuttings or grafted plants of resistant types rather than seedlings.

Oak-Root-Fungus Disease, Armillaria Root Rot.—This widespread pest often attacks specimens of cotoneaster; it causes the foliage to turn yellow and eventually kills the bushes. The typical white, felty, fan-shaped, fungus growth of *Armillaria mellea* is found between the wood and bark of the main root.

No species of cotoneaster has been found to be very resistant to *Armillaria.* Affected plants should be removed, with as much as possible of the roots. See page 84.

Root Rot.—The bushes attacked by this disease die from a rotting of the bark just below ground. The causal fungus, a species of *Phytophthora,* occurs in heavy soil with poor drainage. Excess water should be avoided and drainage improved if possible; otherwise cotoneaster should not be planted in spots where bushes have died in this manner.

COTTONWOOD AND POPLAR

Canker.—The twigs and branches of most species of *Populus* are usually more or less disfigured and injured by cankers and galls. Some of these are caused by insects and some by fungi of probably several different species, but especially a species of *Marssonia.* On trees of value for ornamental purposes, all diseased branches should be removed.

Dematophora Root Rot.—In this disease, caused by the fungus *Rosellinia necatrix,* trees die from a rotting of the roots just as in the disease caused by the oak-root fungus, *Armillaria mellea,* to which this host is also susceptible. Affected trees should be removed with as much of the root as possible.

Leaf Spot, Blight.—The leaves show dead spots and the shoots are sometimes killed back by this disease. Badly affected leaves drop prematurely. Several different fungi, including species of *Marssonia* and *Septoria,* cause leaf spot of cottonwood trees. This disease and the next one may occur on the same leaves. The trees are sometimes greatly disfigured and almost defoliated by leaf spot and rust.

Fallen leaves should be raked and burned to reduce the spread of disease. In the case of trees of particular value for ornamental purposes, spraying with 3-3-50 bordeaux mixture (p. 97) at the first sign of disease might be tried.

Rust.—In this disease, the underside of the leaf is covered with a dense layer of yellow, dusty spores of the fungus, *Melampsora* sp. The leaves

are injured and sometimes drop on account of this disease. Destruction of fallen leaves is the only control that can be suggested.

CURRANT AND GOOSEBERRY, NATIVE

Blister Rust.—Small, yellow rust pustules with dark-brown, hairlike projections are formed in the summer on the lower side of the leaves. If badly affected, the leaves drop off. This is the so-called "alternate form" of the very important rust of the white pine and sugar pine (p. 54). This means that the fungus, *Cronartium ribicola,* cannot infect one pine tree by spores coming directly from another; pines become infected only by spores from currant or gooseberry. Of the native species of *Ribes,* the most susceptible to blister rust are *R. Roezlii, R. Nevadense,* and *R. cruentum.* An effort is being made to exterminate these as well as other native species of currant and gooseberry in the vicinity of susceptible pines, in order to retard the spread of blister rust in this state. The cultivated black currant, *R. nigrum,* is one of the most susceptible species, and its culture is prohibited by law in California. Blister rust is present in Washington and Oregon and has recently been found in the extreme northern part of California.

Any indication of a true rust on wild currants or gooseberries should be reported immediately to the nearest agricultural official.

CYCLAMEN

Blast.—In affected plants, leaves and flowers wilt and dry up on account of a rotting of the stalks at the base. Young flower buds and leaves blacken and die completely. The cause of this disease, a species of *Cylindrocarpon,* is a soil fungus which attacks the crown of the plant.

To control this disease, discard soil in which diseased plants have grown, use fresh soil for potting, and avoid overwatering.

Blight.—Leaves and flowers of blighted plants die and are covered with a gray fungus mold, *Botrytis cinerea.* Overwatering, crowding, and poor ventilation should be avoided.

Leaf Roll.—The leaves of certain plants roll or fold together upwards on the midrib and remain in this position. Nothing is known about the cause or control of this trouble.

Soft Rot.—This is a bacterial rot of the tuber which sometimes occurs; it is caused by *Erwinia carotovora.* Thrifty plants are not often troubled with this disease. No control can be suggested except to destroy affected plants.

Stunt.—Flower stalks of stunted plants are very short so that the flowers are surrounded by leaves (fig. 5). A dark discoloration is seen

on cutting into the top of the tuber where the leaves and flower stalks are attached. This disease has been attributed to the fungus *Cladosporium cyclaminis,* but there is some doubt as to the correctness of this.

To control, use fresh soil for seedbed and potting, and grow the plants at as low temperatures as possible.

Fig. 5.—Cyclamen stunt; note the shortening of flower stalks and discoloration in corms.

CYPRESS, MONTEREY AND ITALIAN

Bark Canker, Coryneum Canker.—Twigs, branches, and eventually whole trees become sickly-looking, defoliated, and finally die as a result of bark canker. This disease is exterminating the Monterey cypress in most parts of California at the present time. The affected twigs show

slightly sunken, dark-colored, resinous, rough cankers, with tiny, black, spore pustules of the fungus *Coryneum cardinale* on the surface. Insect attacks follow and hasten the death of the tree. The Italian cypress is also frequently affected.

No permanent method of control has been found for this disease. Close inspection and cutting out the first cankers to appear will delay its progress. Spraying with 5-5-50 bordeaux mixture (p. 97) before the disease gets too far advanced may be helpful, but this disfigures the trees and cannot be considered a satisfactory control method. Substitution of other kinds of trees for Monterey cypress in windbreaks and other situations seems necessary. Some species of cypress are resistant. For advice in this matter for different localities, consult the county farm advisor, particularly in Orange County, where extensive tests are being made.

Chlorosis.—Bright yellowing of the foliage and stunted growth in cypress and other kinds of trees indicates lime-induced chlorosis described on page 76. This is caused by an excess of lime in the soil.

Cytospora Canker.—This fungus disease, somewhat similar to the preceding, but caused by a species of *Cytospora,* attacks mainly the Italian cypress. It is much faster working than coryneum canker—it spreads through the bark at a rapid rate and kills whole branches in a short time. The treatment is the same as for bark canker.

DAHLIA

Leaf Nematode Blight.—In this disease, the leaves show dead, brown areas as in similar diseases on begonia, chrysanthemum, and other hosts. This tissue contains the microscopic worms, *Aphelenchoides fragariae.* Affected leaves should be burned.

Mosaic, Stunt.—Mosaic plants are usually bushy and dwarfed, with shortened shoots and malformed leaves. The leaves show pale-green or yellow bands along the main veins. Tubers are often thickened and shorter than normal. The virus that causes the disease is present in all the tubers of affected plants and is spread from plant to plant by aphids. All plants showing mosaic or viruslike symptoms should be promptly removed and destroyed. Tubers from such plants should not be used for propagation.

Powdery Mildew.—This is one of the common mildews in which the leaves become covered with a white, powdery, fungus growth, *Erysiphe cichoracearum.* Ordinarily little damage is done by this disease to dahlias, because it does not become abundant until late in the season. Dusting with fine powdered sulfur may be practiced if it seems desirable.

Root-Knot Nematode.—Dahlia tubers often show pimply swellings

or roundish galls (fig. 6) caused by the common root-knot, or garden, nematode, *Heterodera marioni*. The roots are also affected and the plants may be stunted if the attack is severe.

To prevent the trouble, avoid planting affected tubers, which should be destroyed. Infested soil should not be planted with any susceptible crop (p. 82).

Smut.—This uncommon disease has recently been reported from one

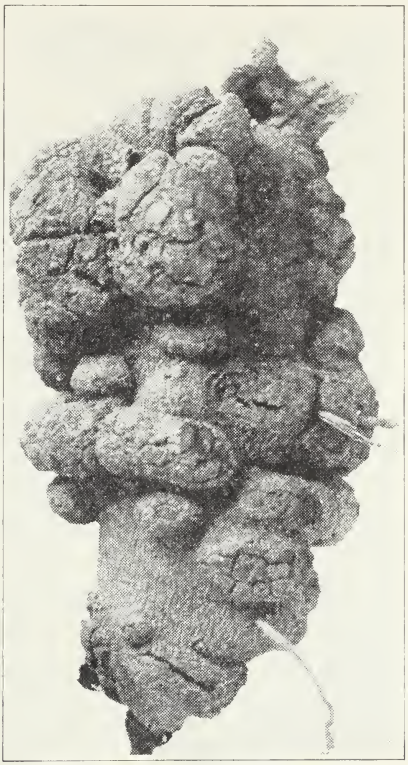

Fig. 6.—Dahlia tuber affected by root-knot nematode.

locality in California. The plants were watered by overhead irrigation, and under such conditions the fungus—*Entyloma dahliae*—spread rapidly and caused an extensive leaf spotting. When this type of watering was discontinued, no new spots developed. If this disease becomes serious, it would be well to destroy affected plants. It may, however, be similar to the closely related disease of calendula (p. 10), which is of very minor importance.

Spotted Wilt.—The new shoots affected by spotted wilt, a virus dis-

ease, look weak and spindling. Yellowish blotches develop on either side of the midvein or between the other veins of the leaves. These become somewhat concentrically ringed and finally the center part of the spots dies and turns dark-brown. This condition is most pronounced in cool weather. When temperatures rise the plants may show considerable recovery. This disease is spread by thrips. See page 90. Also under "Aster" (p. 7) and "Nasturtium" (p. 44).

Badly affected plants should be destroyed to prevent infecting the others. Tubers from diseased plants should not be used for propagation.

Streak, Stem Spot.—In streak disease of the dahlia, small, black, sunken spots appear on the stems and leafstalks. These gradually spread until whole stems may be girdled and sometimes wilt and die. This streak condition is very common on dahlias in California but does not often cause any appreciable damage to the plants. It may be a virus disease; the cause is unknown. Badly affected plants should be destroyed.

DAPHNE

Root Rot.—See under "Fremontia" (p. 30).

DELPHINIUM, OR LARKSPUR

Bacterial Blight.—Infected plants die from a blighting and blackening of the stems, which begins either at the tips or on the main stalk near the ground. The double-flowered, annual type is most affected. The cause is *Erwinia phytophthora.*

Seed treatment seems to prevent this disease, but larkspur seed is very sensitive to such treatment. It is injured or killed, for instance, by soaking in 1–1,000 corrosive sublimate for 10 minutes. Soaking in water at 127.4° Fahrenheit (53° Centigrade) for 10 minutes retards germination and growth somewhat but prevents the disease. Further tests are needed.

Black Spot, Bacterial Leaf Spot.—Large, shiny, black spots with yellow margins occasionally appear on the leaves (fig. 7), and cause them to wither and fall. The disease starts in the older, lower leaves, and progresses upwards until only a bare, blackened stalk remains. It is caused by *Phytomonas delphinii.*

Affected plants should be destroyed. In almost any lot of seedling delphiniums where this disease occurs, some plants usually become badly affected while others are completely immune. The latter can be multiplied by root sprouts.

Crown Rot, Cottony Rot, and Southern Root Rot.—In these diseases, the whole plant withers and dies from a rotting at the crown. A white mold develops around the stem and roots and on the soil, and in this and

on the dead plant parts are found roundish or irregular, solid, seedlike or tuberlike bodies, the sclerotia of the fungus. In cottony rot, caused by *Sclerotinia sclerotiorum* (see "Cottony Mold," p. 78), these are black in color may be ¼ or ½ inch in length; in crown rot, caused by *Sclerotium delphinii*, they are smaller, round, and of a chocolate-brown color; and in southern root rot, caused by *S. Rolfsii* they are of about the size, shape,

Fig. 7.—Black spot of delphinium.

and color of mustard seed (fig. 11, p. 36). These bodies perpetuate the fungus in the soil. Many other plants are attacked by fungi of these types.

If plants become affected, there is no control except to destroy affected plants and dig out the roots; let the soil dry out and do not immediately replant with any kind of plants.

Mosaic.—Delphiniums are affected by several mosaic or virus diseases in which the plants are stunted and dwarfed, or show malformed and yellow leaves or mottled foliage and flowers.

As soon as any such signs of disease appear, destroy affected plants and do not take sprouts or cuttings from such plants.

Powdery Mildew.—The leaves and stems of both perennial delphiniums and annual larkspur sometimes become covered with white mildew fungus, *Erysiphe polygoni.*

Delphinium plants resistant to mildew may readily be found in seed-

ling plantings. These may be propagated by root sprouts. Some mildew-resistant strains are advertised in garden magazines or may be developed by selection. There seems to be a tendency in delphiniums for plants resistant to mildew to be susceptible to bacterial leaf spot. Dusting the leaves with dry, powdered sulfur is of value in preventing mildew.

DOUGLAS FIR, PSEUDOTSUGA TAXIFOLIA

Bacterial Gall Disease.—Roundish, rough-barked swellings or galls, from the size of a pinhead to several inches in diameter, may develop on

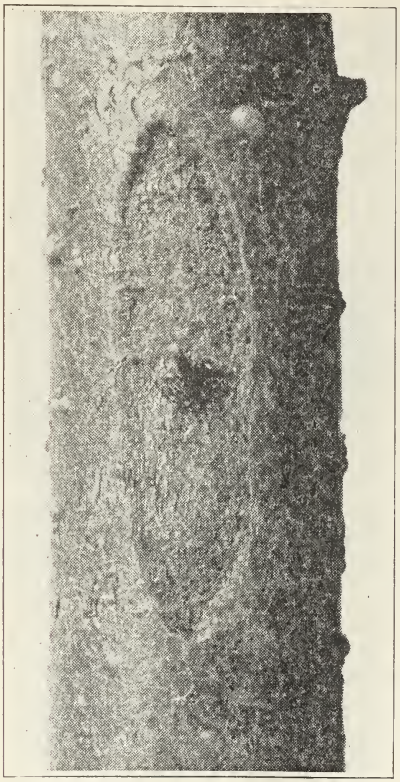

Fig. 8.—Bark canker of Douglas fir.

the twigs, branches, and upper stems. This is due to infection with a bacterial organism, *Phytomonas pseudotsugae.*

Bark Canker.—Long, narrow, elliptical, dead, slightly sunken areas or cankers sometimes appear on the smooth bark, usually on the stems of young saplings (fig. 8). These cankers may be from 1 to 30 inches in length and usually develop around the stubs of dead twigs which have been killed by the fungus *Phomopsis lokoyae.* Small spore pustules may

be seen in the dead bark. Terminal shoots and sometimes the whole tree is killed. This disease, if it should develop abundantly in commercial Douglas fir areas, might become a very serious matter. Thus far, however, it has appeared only sporadically in unimportant districts.

ECHIUM

Dematophora Root Rot.—*Rosellinia necatrix,* a root-rotting fungus which sometimes causes a serious disease on apple and other woody plants, has been reported on this host.

ELM

Dutch Elm Disease.[5]—The leaves on part or all of an affected tree or the tips of some of the side branches, suddenly wilt and often turn yellow or brown before falling. The end leaves usually hang on longer than the others, with a characteristic bending of the tip of the twig. The whole tree may die in one season, or different limbs may become affected one at a time over a longer period. Numerous small brown dots or streaks appear in the sapwood of affected branches, much as in the disease called "blackheart" of apricot. The disease is caused by a fungus, *Ceratostomella ulmi,* which lives in the affected wood and is spread from tree to tree by insects, especially bark beetles or shot-hole borers (species of *Scolytus*). It was introduced into this country from Europe on elm logs imported for lumber and has been the object of strenuous efforts in several eastern states to eradicate the disease by destruction of affected trees. The introduction from affected areas into California of elm nursery trees or elm logs or other dangerous material is prohibited. The Chinese elm (*Ulmus pumila*) has been reported to be less susceptible to the disease than the American (*U. americana*), English (*U. campestris*), or cork elm (*U. racemosa*).

To prevent the Dutch elm disease from being introduced into this state and destroying many valuable shade and street trees, it is advisable that no nursery stock, wood, or lumber of any kind of elm be brought in. Suspicious dying or withering of elm trees should be reported at once to county or state agricultural authorities. When the disease is once present, no method of control is known except immediate destruction of affected trees. Such procedure is a real calamity to many towns and cities.

Slime Flux.—A slimy, fermenting sap or exudate oozing out of the

[5] For further information see:

Clinton, G. P., and F. A. McCormick. Dutch elm disease. Connecticut Agr. Exp. Sta. Bul. 389:697–752. 8 pls. 1936.

McKenzie, M. A., and W. B. Becker. The Dutch elm disease. Massachusetts Agr. Exp. Sta. Bul. 343:1–16. 6 figs. 1937.

May, Curtis, and G. F. Gravatt. The Dutch elm disease. U. S. Dept. Agr. Cir. 170: 1–10. 6 figs. 1931.

bark on the trunk, attracting flies, yellow jackets, and other insects, indicates slime flux. The bark beneath may be killed down to the wood in considerable areas. This probably originates in a flow of sap or "bleed-

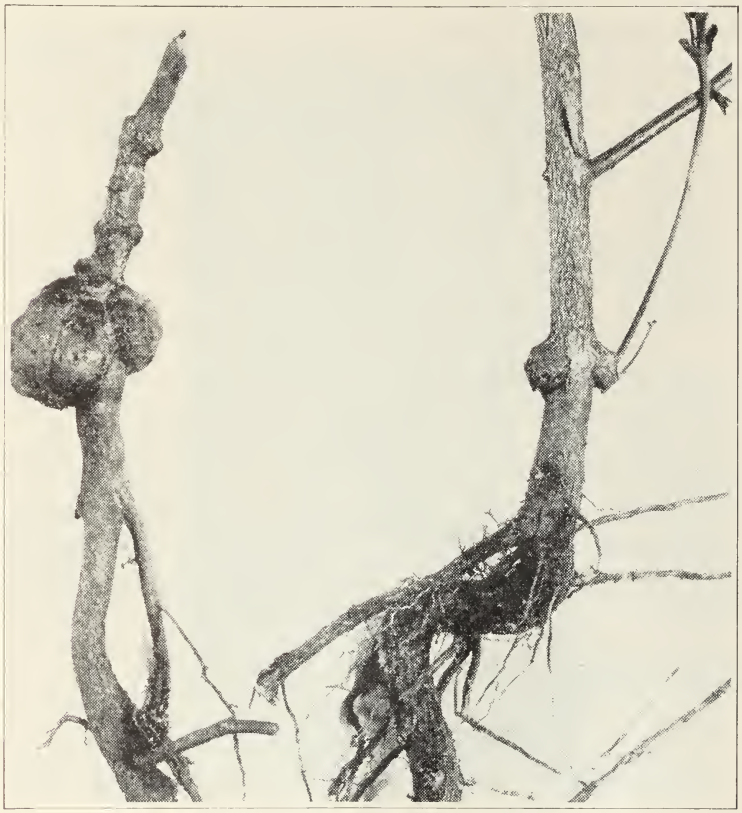

Fig. 9.—Crown knot of eucalyptus.

ing" from a wound of some sort in the bark, which becomes contaminated with bacteria and yeasts that cause fermentation.

Bark areas of this sort should be washed and scraped off as clean as possible, all decaying and dead bark should be cut out, and the exposed surfaces washed with corrosive sublimate solution 1-1,000 (p. 100) or a solution of copper sulfate, 1 ounce to 1 gallon of water. This may be repeated as long as bleeding continues, after which the wound may be covered with bordeaux paste (p. 98).

EUCALYPTUS

Chlorosis.—In places where there is a considerable amount of lime in the soil, eucalyptus and other kinds of trees often show poor, stunted growth and bright yellow foliage. See page 76.

Crown Knot.—Rounded, smooth, hard, woody swellings or galls often develop on the stems of young eucalyptus seedlings near the ground (fig. 9). This condition is often mistaken for crown gall, but appears to be normal or at least harmless.

Leaf Spot and Twig Canker.—Leaves are sometimes marked with dead spots and the twigs become cankered and killed, but the trouble, caused by *Hendersonia eucalypti* and *Phyllosticta extensa,* is not important. All species of eucalyptus are singularly free from fungus diseases in California.

Wood Decay.—The fungus *Polyporus sulphureus* very commonly forms large clusters of conspicuous, bright-yellow, bracket fungi on trunks of eucalyptus trees. Such trees are affected by a heart rot caused by this fungus.

EUONYMUS

Powdery Mildew.—On the popular, glossy-leaved, evergreen shrub, *Euonymus japonica,* and its variegated-leaved varieties, this mildew is exceedingly persistent. The leaves are covered with a dense, white mat of the fungus *Microsphaera alni,* especially in shady places.

This disease might be at least partially controlled by thorough dusting with dry sulfur or spraying with lime-sulfur 1-100 (p. 101), but as a rule it is better to substitute some other shrub in places where mildew is very troublesome.

FERN

Leaf Nematode Blight.—See under "Begonia" (p. 9).

FIR, DOUGLAS

See "Douglas Fir," *Pseudotsuga taxifolia* (p. 25)

FIR, WHITE

Needle Cast.—In this disease of white fir, *Abies concolor,* caused by a fungus, *Hypodermella abietis-concoloris,* the needles of young trees turn reddish gray, with black lines along the middle on the underside. All but the youngest needles at the tips of the trees are affected.

Nothing can be done to control this disease in the forest. In the nursery, spraying with bordeaux mixture (p. 97) may help.

FREESIA

Red Bulb, Stem Rot, Corm Rot.—In this fungus disease caused by a species of *Fusarium,* the tops of plants growing in the field for corm production become dark-colored, blighted, and dead from a rotting at the base of the stem. Matured corms show dark-colored spots on the surface at

the base or at the core, and are destroyed in storage by a dry rot (fig. 10). Freesias of the Purity type, and particularly some of its strains, are especially susceptible to this disease.

Affected corms must be very carefully eliminated from planting stock by throwing out all which show any decay or discoloration on the surface

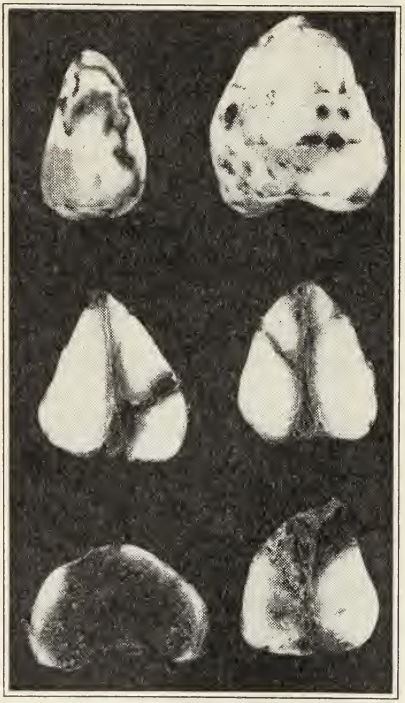

Fig. 10.—Freesia corm rot.

or at the core. The latter can usually be detected by discoloration of the basal hollow. Plant only in fresh soil which has not recently been used for freesias or gladioli. As an extra precaution, corms may be soaked for 2 hours before planting in 1-1,000 corrosive sublimate (p. 100). Most of the infection, however, is inside the corms and so cannot be reached with any treatment but can only be eliminated by sorting the planting stock.

Rust.—In mild, foggy districts close to the ocean in southern California where many freesia corms are grown, the leaves, flower buds, and stems sometimes become covered with a bright-red, rusty, superficial, spotted discoloration, and the tops are blighted and ruined. This happens after periods of wet, foggy weather. It is not a true rust; the cause is unknown. If this trouble is serious, no method of control is known except to grow freesias in less exposed places.

FREMONTIA

Root Rot.—Potted plants under propagation may wilt and die from a rotting of the crown and main root caused by a soil fungus, *Phytophthora cactorum.* The native California shrubs *Fremontia californica* and *F. mexicana* are very susceptible to soil moisture and soil fungi and sometimes give considerable difficulty in propagation on account of this and the next disease.

Clean, fresh soil should be used for propagating these species, and steam-sterilizing it is desirable if possible. Care should be taken to avoid overwatering.

Verticillium Wilt, Verticilliosis.—In this disease, the plants slowly wither and the leaves fall. The cause of the disease is the same soil fungus which produces blackheart of apricot, blue stem of raspberries, and wilt of many different plants—*Verticillium albo-atrum.* See general discussion on page 92. Treatment for this disease is like that for the preceding.

GARDENIA

Canker.—A rough, swollen canker sometimes girdles the stem just above the ground, eventually killing the plant. This is caused by a fungus, *Phomopsis gardeniae,* that enters the plant through cracks or wounds in the stem.

Affected plants should be destroyed, and any pots, soil, or other material which has been in contact with them should be discarded for the propagation of gardenias. Cuttings should not be taken from any stocks which contain plants affected with this disease. Newly propagated plants should not be kept in close proximity to old ones that are affected with canker.[5a]

GAZANIA

Cottony Rot.—Plants sometimes die from a rotting of the stems and roots caused by a cottony, white fungus, *Sclerotinia sclerotiorum.* Black fungus sclerotia develop on the dead stalks. This plant is one of the many hosts of this common fungus (see "Cottony Mold," p. 78). To control the disease, dig out affected plants and allow the soil to dry as much as possible.

GERANIUM

Bacterial Leaf Spot.—The leaves of affected plants show numerous small dead spots which may produce defoliation. The cause is a bacterial organism, *Phytomonas pelargoni.* Avoid wetting the foliage.

[5a] For further information, see: Pirone, P. P. Diseases of the gardenia. New Jersey Agr. Exp. Sta. Bul. 679:1–10. 1940.

Damping-off.—Plants, especially cuttings, occasionally rot off at the base with a soft, black fungus decay caused by a species of *Pythium.* Frequently the inside of the stem is destroyed, and only a hollow shell left, which supports the plant for a time. Stems to be used for cuttings should be allowed to dry for 2 or 3 days before planting, and overwatering should be avoided.

GERBERA, OR TRANSVAAL DAISY

Powdery Mildew.—The plants affected with this disease are stunted and covered with a typical white growth of mildew fungus, *Erysiphe polygoni.* If control is necessary, dust with sulfur.

Root Rot.—Gerberas are very susceptible to a rotting of the roots and crown caused by the fungus, *Phytophthora cryptogea.* The crowns of the plants should be kept well above ground and overwatering avoided.

GLADIOLUS

Dry Rot.—The leaves of affected plants turn yellow and die from a rotting at the neck of the plant. The roots may also decay. Numerous small, black bodies (sclerotia) of the fungus *Sclerotium gladioli,* develop on affected tissue. Round, black, sunken lesions develop on the corms. These are very similar to the spots caused by hard rot and scab. Dry rot of the corms progresses in storage so that they may be completely destroyed. For control see the last section on this flower.

Fusarium Rot, Fusarium Yellows.—This has usually been considered a storage rot although much of the infection starts in the field. The disease, caused by *Fusarium oxysporum* var. *gladioli,* may not show at the time of digging or there may be small, water-soaked spots on the corms beneath the scales, especially on the lower half. These spots enlarge in storage, form large, irregular, brown areas with concentric ridges, and finally convert the entire corm into a hard, dry, brownish-black mummy. In California the fusarium disease may also cause heavy losses by attacking corms of susceptible varieties in infested soil and killing the plants before blooming or while forming the flower stalk. There is evidence at hand which shows that some varieties are very resistant to the disease, others very susceptible. The causal fungus lives in the soil at least four or five years. For control see the last section on this flower.

Hard Rot, Leaf Spot.—This disease attacks both the leaves and the corms. On the latter, small, dark-colored, water-soaked spots appear under the scales in the fall, usually on the lower half of the corm. These spots spread or coalesce until the whole corm is reduced to a hard, shriveled, wrinkled mummy. Hard rot of the corms can scarcely be distin-

guished from the effects of dry rot. On the leaves this fungus, *Septoria gladioli,* produces minute brown or purplish-brown discolored areas which grow or coalesce into large dead spots. The older spots have a light-gray center dotted with numerous black spore pustules. For control see the last section on this flower.

Mosaic.—The plants affected by this virus disease are dwarfed, have mottled leaves, and flowers of broken color (streaked with greenish-white markings). Affected plants should be removed and burned. Great care should be taken not to propagate from such stock.

Penicillium Rot.—Corms in storage sometimes rot, the infected tissue being pale green to brown, with a greenish border and a cheesy or corky consistency. At low temperatures a blue-green fungus mold, *Penicillium gladioli,* grows out over the surface. Infection starts at wounds produced in digging or handling the corms or very often at the point where the stem and leaves were attached. Freshly dug corms are more susceptible. For control see the last section on this flower.

Scab.—This infection, caused by *Phytomonas marginata,* is usually the most serious disease of gladiolus in California. Small, water-soaked, light-brown spots appear on the leaves just above the ground level. These enlarge and coalesce, the leaves turn yellow at the tips and may rot off at the base, so that the whole plant falls over. On the corms, dark-margined spots appear on the husks and below these develop dark-brown and black sunken areas with a distinctly raised margin. These may become ¼ inch or more in diameter and are often covered with a brittle, gummy exudation. For control see the last section on this flower.

Thrips.—The effect produced by gladiolus thrips, *Taeniothrips gladioli,* may easily be mistaken for a disease. The flowers are attacked in the bud and become blasted and malformed so as to be worthless, while the leaves show a silvery, dried condition. For control of the thrips, see Circular 346.[6]

Control of Gladiolus Corm Diseases.—The diseases described under "Dry Rot," "Fusarium Rot," "Hard Rot," "Penicillium Rot," and "Scab" all cause spotting and rotting of the corms and are distributed by planting diseased stock. Some of them develop and increase in storage. The fungi which cause most of them live over in the soil so that clean stock may become infected by planting in soil where gladioli have previously grown. Prevention of these diseases resolves itself, therefore, into four phases: use of clean stock, treatment of corms by dipping, rotation or planting on new soil, and proper curing and storage methods.

[6] Bailey, Stanley F. Thrips of economic importance in California. California Agr. Exp. Sta. Cir. 346:1–77. 40 figs. 1938.

Corms, after digging, should be dried, cleaned, and cured as quickly as possible and all diseased or spotted ones destroyed. They should then be stored in a dry, well-ventilated place. A temperature as low as 40° Fahrenheit helps to prevent rot. Just before planting, they should be carefully re-sorted and all diseased ones again eliminated; dipping is of no value to corms which are already diseased. The planting stock should be soaked in a 1-1,000 corrosive sublimate solution (p. 100) for 2 hours in a wooden vessel. There are other materials which may be used, but this is cheap and effective. Planting should follow immediately. A well-drained soil should be chosen, and, in places where there has been much trouble with diseases, it will be much better if land can be found which has not been used for gladioli for at least four years. If it is necessary to fumigate the corms for thrips, this should be done before dipping.

GLOXINIA

Bud Rot.—The buds sometimes die and are covered with a dense growth of the gray mold fungus, *Botrytis cinerea*. This condition usually indicates poor ventilation and excessive humidity in the greenhouse.

Leaf Nematode Blight.—See under "Begonia" (p. 9).

GOOSEBERRY, NATIVE SPECIES

See "Currant and Gooseberry, Native" (p. 19)

HAWTHORN

Fire Blight, Blight.—Many species of hawthorn (*Crataegus*) are susceptible to the bacterial disease commonly called "pear blight," caused by *Erwinia amylovora*. The leaves wither and twigs or branches die as in the pear and apple. The English hawthorn, *C. oxyacantha*, is particularly susceptible.

Valuable specimens, when not too badly affected, may be saved by cutting out diseased branches. See under "Cotoneaster" p. 17). Blight-affected hawthorns should not be neglected and allowed to become a source of infection for pears and apples. If they cannot be treated successfully, all such trees should be destroyed.

Rust.—Several species of true rust fungi of the genus *Gymnosporangium* affect hawthorns. Thickened, yellow spots with spore pustules are produced on the underside of the leaves. These fungi also attack apples and other pomaceous fruits and, in one stage of their life history, are found on cedar and juniper trees. The disease is not common in California.

Sooty Mold.—Affected foliage is crusted over with a dirty, black fun-

gus growth. This is also often seen on citrus trees, olives, oleanders, and other plants. This "smut" or mold, caused by species of *Fumago, Meliola,* and *Capnodium,* does not really grow upon the tree itself but develops upon the sweet, sticky liquid or honeydew which is secreted by insects like aphids, scale insects, and white flies. Sooty mold is not in itself injurious to the health of plants but is very disfiguring to fruit, foliage, and flowers, and its presence indicates that some insect pest is abundant. The hawthorn tree is almost always affected in this manner, being first attacked by aphids on the undersides of the leaves. These secrete honeydew upon which the sooty mold develops.

Spraying with a solution composed of 1 pint of 40 per cent nicotine sulfate (Black Leaf 40), 1 gallon of commercial lime-sulfur solution, and 1 gallon of summer-oil emulsion, to 100 gallons of water will clean up both sooty mold and aphids.

HEATHER, OR ERICA

Chlorosis.—See under "Azalea" (p. 8).

Root and Crown Rot.—Some of the plants wither and die from a rotting of the roots and base of the stem. The fungus disease, caused by a species of *Phytophthora,* is favored by overwatering and anything which weakens the plants. Affected ones are often found to be badly "pot-bound," a condition which makes the roots more subject to trouble of this sort. To control the disease, be careful to obtain good plants with a healthy root system, and avoid overwatering.

Rust.—The leaves of heather affected with rust show little pustules of the red spores of the fungus *Uredo ericae,* which may defoliate the plants. Dusting with dry sulfur has given good control of this disease. Treatment should be started at the first sign of rust.

HETEROMELES

See "Photinia, Heteromeles, or Toyon" (p. 52)

HEUCHERA

Rust.—The leaves are blighted and show on the undersides conspicuous brown spore pustules of the fungus *Puccinia heucherae.* Affected leaves should be destroyed and the plants dusted with sulfur.

HOLLYHOCK

Oak-Root-Fungus Disease, Armillaria Root Rot.—Hollyhock plants are sometimes attacked by the omnivorous fungus parasite *Armillaria mellea,* which is the cause of so much damage to fruit trees and other woody plants (see p. 84). When thus diseased, the tops of the plants wither and

die and the main root or crown is rotted and permeated with the white, felty tissue of the fungus. Affected plants should be taken out and destroyed, with care to remove all the roots and the soil adjacent to them.

Rust.—In this disease, prominent, solid pustules of fungus spores, *Puccinia malvacearum,* push out on stems and on the undersides of the leaves; these then turn brown and die, and the plants become very shabby-looking. The common mallow is also affected.

Dusting with dry sulfur before the plants become badly affected is of some value. Cutting out and burning all the old stalks as soon as they are badly rusted is advisable; the new ones which come up later in the season may be less affected. But at least every two years all old plants should be destroyed and a new start made from seed.

HYACINTH

Nematode, Eelworm, Stem Nematode.—See under "Narcissus" (p. 43).

Soft Rot.—The bulbs may be destroyed by a soft, slimy, bacterial rot, caused by *Erwinia carotovora,* either before or after growth has started. In the latter case the plants are stunted and sickly-looking and finally die. Flower heads or leaves may also be infected and killed, showing first a brown discoloration.

This trouble may result from some injury like freezing or overheating while the bulbs are in transit, which makes them susceptible to soft rot. In some cases imported bulbs appear to have been infected before leaving Europe.

HYDRANGEA

Chlorosis.—The leaves of affected plants become yellow or almost white and the plants stunted and sickly. The trouble occurs mostly in heavy soil inclined to an excess of lime or alkali and may become worse with heavy watering. To control, dig up the soil deeply and add sand and manure. Try light applications of ammonium sulfate, aluminum sulfate, or sulfur, and the use of more or of less water than before.

INCENSE CEDAR

Pecky Heart Rot.—Of the many wood rots which attack timber trees, this one, caused by *Polyporus amarus,* is mentioned on account of its very characteristic effect on the native incense cedar, *Libocedrus decurrens.* In this form of decay, numerous, elongated, hollow pockets from ½ to 12 inches long are formed in the wood. They contain a brown friable mass of decayed wood which disintegrates and falls out when the pocket is cut across, leaving clean, open holes about ½ inch in diameter running longitudinally through the solid wood. Externally, the fungus forms

large, hoof-shaped conks or fruiting bodies attached to the trunk at branch stubs or knotholes; the upper surface is light brown, the lower yellowish green. These are very short-lived, being quickly destroyed by insects.

Witches' Broom, Rust.—In the native incense cedar, numerous large and small witches' brooms or masses of short branches are caused by a

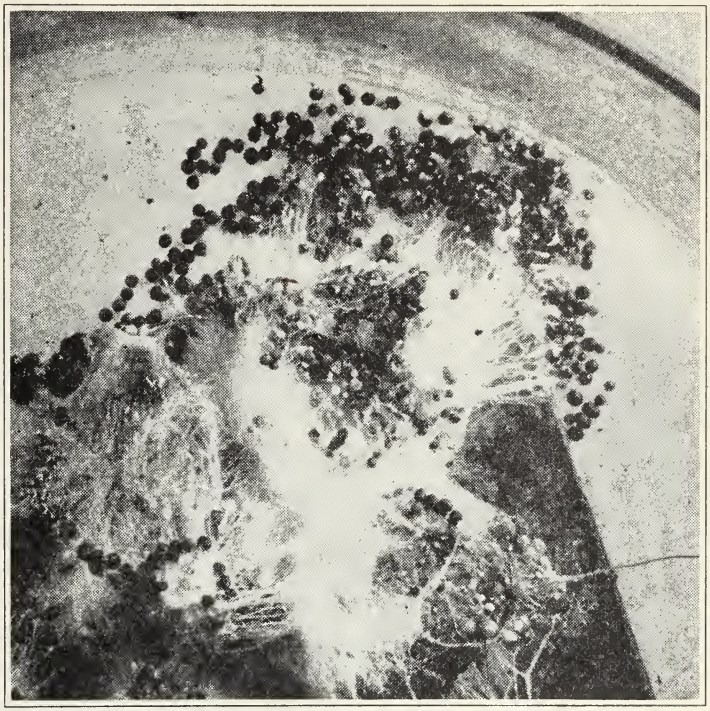

Fig. 11.—Sclerotial fungus that causes root rot of iris.

fungus, *Gymnosporangium libocedri.* Another or alternate stage of the same fungus lives on trees of the apple and pear family and causes a rust of the leaves and fruit. The latter stage, in California, attacks native hosts like shad bush and has been observed on pear.

IRIS

Leaf Spot.—Small, translucent spots which gradually enlarge and become yellow, sometimes appear on the leaves, the center of the older spots being gray with a brown border. As a result of this, the leaves are killed. The cause is a fungus, *Didymellina macrospora.* If this disease is present, all the old, dead leaves should be cleaned up and burned before new growth starts in the spring.

Mosaic.—The foliage of iris affected by mosaic is streaked with light, yellowish-green areas and the plants somewhat stunted. This disease, which is more severe on the bulbous than on the rhizome type of iris, is caused by a virus. Affected plants should be destroyed if the disease is serious. Plants showing mosaic symptoms should not be used for propagation.

Root Rot, Crown Rot.—Crowns and leaf bases of the plants may be rotted by a white mold fungus, *Sclerotium Rolfsii* or *S. delphinii,* which

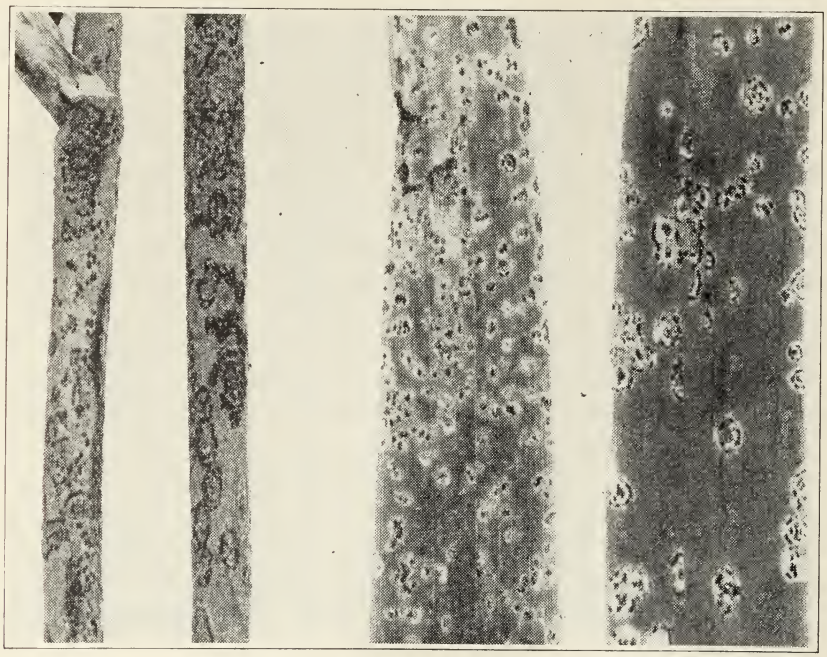

Fig. 12.—Iris rust.

forms numerous, small seedlike bodies or sclerotia (fig. 11) on the surface of the affected plants. *S. Rolfsii* also attacks sugar beets and many other hosts.

Affected rhizomes should be dug out and destroyed. The remaining ones should be thinned and replanted, if possible in a new place.

Rust.—Powdery pustules of reddish-brown spores of a rust fungus, *Puccinia iridis,* may appear on the leaves (fig. 12), which may be killed prematurely if the infection is severe. Most of the commonest species and varieties of iris are fortunately immune to this disease. When the tops are cut back, all diseased leaves should be carefully collected and burned.

Soft Rot.—When the rhizomes have become thickly matted or are in heavy, poorly drained soil, a soft, slimy, bacterial rot, caused by *Erwinia*

carotovora, sometimes attacks the rhizomes and destroys the internal tissue so that only a hollow shell remains.

Affected rhizomes should be dug and destroyed. The remaining ones should be thinned and replanted, if possible in a new place.

JUNIPER

Blight.—This fungus disease, caused by *Pestalozzia funerea,* has been reported as resulting in a heavy loss of small trees in one nursery. For any disease of this sort, thorough spraying of the young plants with bordeaux mixture (p. 97) at the first appearance of the trouble may be suggested.

Rust.—In eastern states, the rust attacking apple and native juniper trees is a very common and important disease. In California imported Asiatic juniper trees occasionally show rusts of this type from having become infected in the Orient. No rust of this sort has ever become established here. Native junipers in California grow in such out-of-the-way places that their diseases are seldom a matter of observation. Symptoms of the disease are swellings on the branches or leaves, from which develop gelatinous, yellow masses of spores of a species of *Gymnosporangium.* Another stage or form of the same fungus attacks apple and pear trees. See "Witches' Broom, Rust," under "Incense Cedar," page 36.

LAWN GRASS, OR TURF

Black Mold.—A smutty, dusty, black-mold growth sometimes develops abundantly on the turf and grass blades in wet weather. This growth is one of the so-called slime molds, a species of *Physarum.* It is entirely superficial and does not injure the grass except in appearance. Vigorous spraying with the hose will wash off most of this growth, which usually disappears of itself after a short time.

Brown Patch.—In this disease, the grass dies and turns brown in patches which may gradually enlarge until areas of bare soil several feet in diameter are formed. This is most common in young lawns. The common *Corticium* (*Rhizoctonia*) fungus, *C. vagum,* which attacks many other hosts, is the usual cause of this; but other molds, soil fungi, and damping-off organisms like *Pythium, Fusarium,* and *Botrytis* are often responsible. Moist weather, high soil moisture, and shade favor the disease. On heavily fertilized soil, especially if rich in nitrogen, the trouble is more likely to develop.

Various worms or insect larvae also attack lawns, killing the grass in patches in a manner similar to brown patch. For methods of control see Extension Circular 87.

When brown patch appears, avoid overwatering; keep the lawn as dry as possible. Water in the middle of the day rather than late in the afternoon. If heavy dew forms on the grass during the night, its drying-off may be hastened by sweeping the surface lightly in the morning with some sort of large broom or brushlike device. Do not use animal manures or nitrogenous fertilizers on lawns containing brown-patch spots.

Chemical treatment may be used to check the disease after it has started. For this purpose, some of the compounds of mercury have been found effective, commonly a mixture of one-third corrosive sublimate and two-thirds calomel, applied either as a spray in water or mixed with dry sand, soil, or fertilizer and broadcast over the turf. In severe, active cases, the mixture may be made up with one half of each material. Two ounces of the mixture should be added to 5 gallons of water; this will cover 500 square feet of lawn. Corrosive sublimate dissolves in hot water but only slowly in cold. Calomel is insoluble in water and therefore the mixture must be kept well stirred while it is being sprayed or sprinkled onto the lawn. Wooden or glass containers should be used when possible. Metal containers should be thoroughly rinsed immediately after use. For a dry application, 4 ounces of the combined mercury salts should be thoroughly mixed with a bucketful of sand, soil, or fertilizer and broadcast over 1,000 square feet of turf. There are also several commercial preparations on the market for control of brown patch; these should be used according to directions. During dry weather the lawn should be watered lightly after applying any of the chemicals. Applications may be repeated at 2-week intervals if necessary. Where serious trouble with brown patch exists, different kinds of grasses should be experimented with to find what is best suited to the particular locality.

LILAC

Mildew.—The leaves of lilac bushes very often become covered with a dirty-gray growth of the fungus *Microsphaera alni*. Dusting with sulfur would be the best treatment if any is tried.

Seasonal Effects.—After warm winters during which little frost occurs, lilacs, like many fruit and other trees, may fail to start growth properly in spring and struggle along in a very irregular fashion. Nothing can be done to prevent or remedy this.

LILY

Blight.—On affected plants, dead spots develop on the leaves or stems, and these and the buds may be covered with a grayish mold, *Botrytis elliptica*. Young plants are killed by rotting of the stem and crown. This

fungus disease occurs at times or in places where there is a great deal of moisture present. To control the disease, destroy affected parts and keep the plants and soil as dry as possible.

Foot Rot.—Plants die from a rotting at the base where the fungus *Phytophthora cactorum* attacks the stem and root. This is favored by excessive moisture. To control it, destroy affected plants and avoid overwatering.

Leaf Nematode Blight.—See under "Begonia" (p. 9).

Mosaic.—Mosaic leaves show a green and yellow mottling or streaking and become somewhat stunted and deformed. Dead spots may develop. This results in poor growth of the plants and blossoms. In plant beds, the disease, which is caused by a virus, is spread by aphids.

This disease is transmitted in the bulbs, which should, therefore, come from a reliable source. Affected plants should be destroyed, when grown either for flowers or for bulbs. In the latter case, any diseased plant which shows up in the bed should be immediately removed and the growing plants should be kept thoroughly sprayed to control aphids.

LUPINE

Rust.—The leaves of affected plants become blighted and covered with reddish spore pustules of a true rust, *Uromyces lupini.* Badly affected plants should be destroyed. Dusting with sulfur may help to hold the disease in check.

MADRONE

Leaf Gall.—The leaves are sometimes disfigured by a fungus, *Exobasidium vaccinii,* which produces circular areas on the lower surface, where the tissue is at first swollen and spongy, then dries down to a cupped or blistered depression, with a raised dome on the upper side. For control, see the last section under this tree.

Leaf Spot.—In this disease, the foliage shows numerous purplish-black fungus spots, caused by *Mycosphaerella arbuticola.* Defoliation of the trees may result.

Rust.—The leaves are marked with numerous reddish pustules of spores of the fungus *Pucciniastrum sparsum.*

Stem Canker.—Black, dead areas or cankers develop on the stems and branches, finally killing them and causing the leaves to wither but remain hanging on the tree for some time. The cause of this is unknown but may be, at least in part, the leaf-spot fungus mentioned above.

Tar Spot.—Large, very prominent, black areas dotted with minute spots develop on the underside of the leaves. The cause of the disease is a fungus, *Rhytisma arbuti.*

Control of Diseases of Madrone.—The madrone, a native tree of California, has no value as a timber species, but it is frequently of considerable importance as a shade and ornamental tree. Under such conditions, anything which disfigures the foliage may be of real concern to the owner. No actual experience is available regarding the control of these diseases. Sanitary measures, such as the raking and burning of diseased leaves and careful pruning out of all cankered or diseased branches, are decidedly advisable. Spraying with bordeaux mixture (p. 97) in March every year might be of some value as a general cleanup, or a spray of 1 gallon of lime-sulfur solution (p. 101) in 100 gallons of water might be tried. The bordeaux mixture will disfigure the leaves temporarily.

MAPLE

Verticillium Wilt, Verticilliosis.—The leaves on affected trees wither and fall, branches die, and this may be followed by the gradual death of the whole tree. This disease seems to be increasing among the street tree and roadside plantings of maples. The same fungus, *Verticillium albo-atrum,* causes diseases of apricot, tomato, and other hosts. See general discussion on page 92. Nothing can be done to control this trouble except to remove badly affected trees and plant some other species.

MARGUERITE

Leaf Blight.—The leaves are marked with whitish, irregular bands or lines which disfigure and kill them. This is often mistaken for the effect of a fungus. The cause is an insect, the chrysanthemum leaf miner, *Phytomyza chrysanthemi.* The adult is a small fly; the young, tiny maggot burrows between the two surfaces of the leaf. The same species infests chrysanthemums and cinerarias. Extension Circular 87 recommends spraying with one part 40 per cent nicotine sulfate (Black Leaf 40) to 600 parts of water for the control of this pest.

MARIGOLD, OR TAGETES

Rust.—This is a true rust with bright orange-yellow spore pustules on the underside of the leaves. The fungus, *Coleosporium madiae,* also has a form or stage on Monterey pine. It is not important.

Wilt.—The plants wilt and die from a rotting of the roots and lower stems, as in many similar fungus diseases. The cause is a species of *Fusarium* or *Phytophthora.* Marigolds should not be replanted in soil where this disease has been severe.

MULBERRY

Blight.—Leaves and twigs may be killed by this bacterial disease in a manner resembling fire blight (see under "Cotoneaster," p. 17), but it is not serious. The cause is *Phytomonas mori.*

NARCISSUS[7]

Basal Rot, Fusarium Rot.—The bulbs in storage, or sometimes when dug from the ground, may show a rather dry rot, starting around the basal plate and extending into the fleshy scale bases. A white or pinkish-white fungus mold, a species of *Fusarium,* develops on the surface.

To control this disease, sort out and discard all defective bulbs in dig-

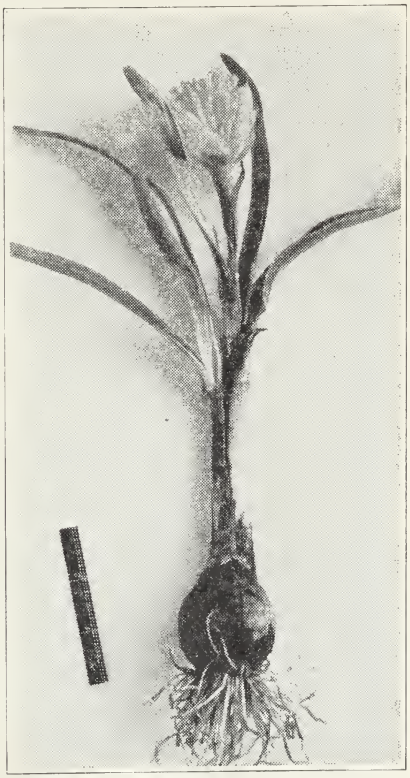

Fig. 13.—Narcissus mosaic disease.

ging, avoid rough handling, and cure the bulbs carefully. Treatment by dipping is discussed at the end of this chapter.

Leaf Scorch.—The fungus *Stagonospora Curtisii* sometimes causes a blighting of the foliage, starting at the tip and finally killing the entire leaf. This greatly weakens the plants. Spraying with bordeaux mixture helps to stop the spread of the disease.

Mosaic, Gray Disease.—Mosaic plants are stunted and lacking in

[7] For further information on narcissus diseases see: McWhorter, Frank, and Freeman Weiss. Diseases of narcissus. Oregon Agr. Exp. Sta. Bul. 304:1–41. 21 figs. 1932.

vigor (fig. 13). The leaves show mottling with definite streaks of green and pale-yellow and the flowers "break," or in other words, exhibit prominent, translucent, clear areas in the petals. The stems of mosaic flowers are shortened. The disease is due to a virus.

Affected plants should be removed and destroyed just as soon as they can be detected. It is also advisable to take out the two adjoining plants in the row. Continuous, careful roguing in this manner will soon clean

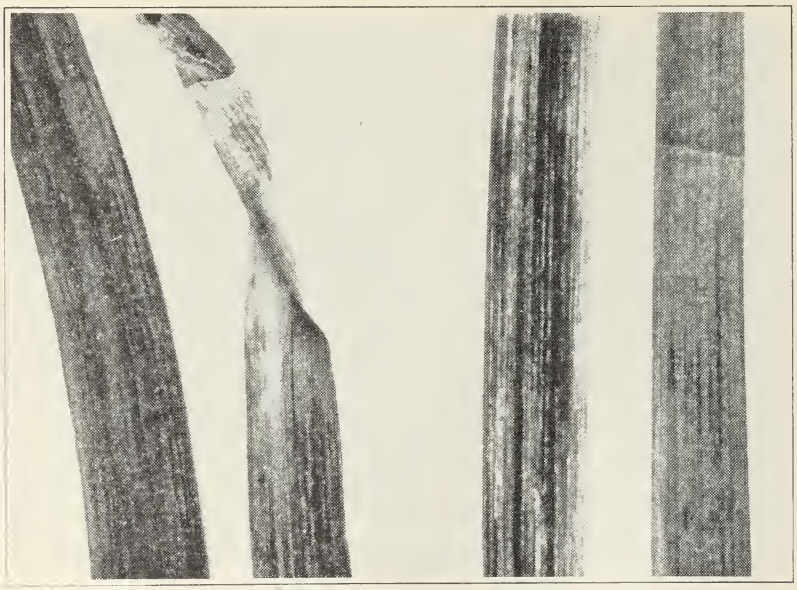

Fig. 14.—Narcissus leaves showing stem-nematode effect.

a planting of bulbs of mosaic, whereas carelessness about the disease may soon bring about the ruin of the entire stock.

Nematode, Eelworm, Stem Nematode.—Affected leaves are yellow and twisted and show yellowish, elongated, raised streaks or ridges on the surface (fig. 14). When the bulb is cut across, dark-brown rings are prominent in the scales. Living worms (*Ditylenchus dipsaci*) may be seen with a low-power microscope or hand lens (fig. 15) if bits of leaf or bulb tissue are crushed in water.

Badly infested stocks should be entirely destroyed unless they are of exceptional value. Affected plants should be rogued out in the field as soon as they can be detected, and the plant on either side taken out. Planting stock should be carefully sorted before and after treatment to remove all bulbs showing signs of decay or injury.

Treatment consists in dipping the bulbs in water at a temperature

which will kill the worms but not injure the bulbs. For this purpose, the bulbs should be soaked in water maintained at a temperature of not less than 110.0° nor more than 111.5° Fahrenheit for not less than 3 hours, computed from the time the water reaches the minimum temperature after the bulbs have been submerged. Bulbs over 2 inches in diameter should be soaked for 4 hours. To prevent the development of rot and otherwise improve the efficiency of the treatment, some recommend the

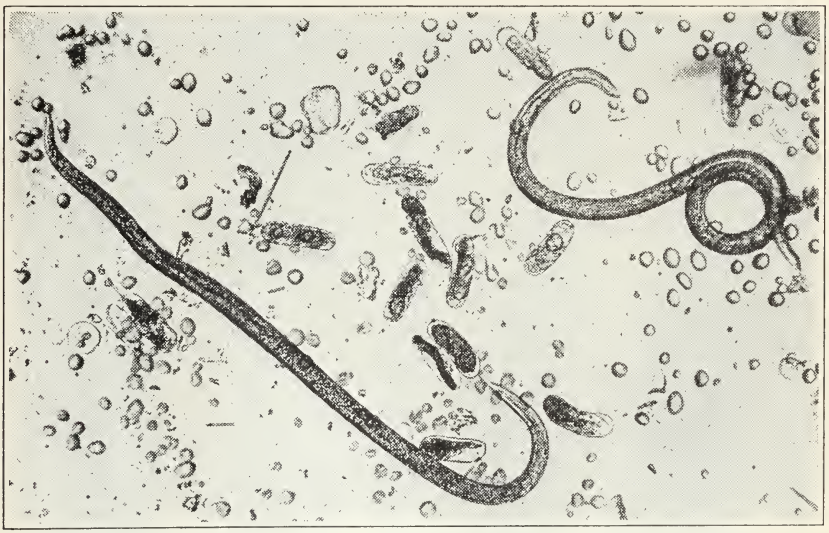

Fig. 15.—The narcissus stem nematode, with young worms and eggs. (Enlarged nearly 150 times.)

addition of commercial formaldehyde (formalin) to the hot water at the rate of 1 pint to 25 gallons of water. It is advisable to try this first on a small scale before treating large numbers of bulbs. Dipping should be done within 2 to 5 weeks from the time of digging the bulbs, the interval being longer the earlier in the season the bulbs are dug. The bulbs may be planted at any time after treatment. If more than a day or two elapses before planting, they should be spread out and thoroughly dried. Commercial growers who are raising bulbs for sale should get in touch with their county agricultural commissioner or state department of agriculture for further details and regulations concerning treatment for nematode and other pests.

NASTURTIUM

Spotted Wilt.—Affected plants are stunted, the leaves crinkled and deformed and marked with yellow spots (fig. 16). This disease, caused by a virus, attacks many kinds of plants. The nasturtium is a common host

for the disease, which may spread from it to other kinds of plants. The infection is spread by thrips. Affected plants should be promptly destroyed. See page 90.

OAK

Blight and Canker, Anthracnose.—Dead spots and blotches sometimes develop on the young leaves and on the sides of the twigs and form cankers on the latter if the shoot is not entirely killed. Trees are sometimes defoliated by this disease in humid districts. The fungus *Gnomonia ve-*

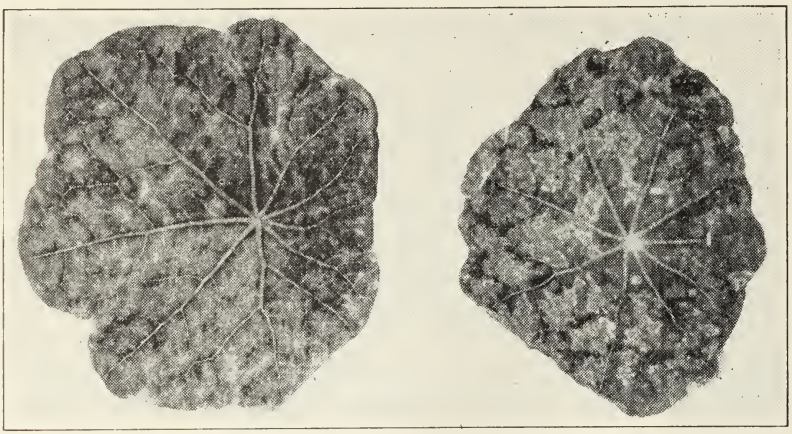

Fig. 16.—Nasturtium leaves affected with spotted wilt.

neta, which is the cause of the very common similar disease of the sycamore tree, seems to be responsible for this condition. A number of other leaf spot or blight fungi occur on oaks in California. For control, see the last section under this tree.

Leaf Blister, Curl Leaf.—Symptoms of this disease are roundish, swollen, blisterlike patches on the underside of the leaves, and corresponding yellowish areas on the upper side. These spots finally die and if badly affected by the fungus (*Taphrina coerulescens*), the leaves may fall, more or less defoliating the tree. For control, see the last section under this tree.

Leaf Spot.—The leaves are often marked with dead spots, which sometimes cause defoliation. Many different fungi have been reported on oaks in California as having this effect, but none is sufficiently important to warrant special treatment here. For control, see the last section under this tree.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Affected trees die or are weakened and break over from a rotting of the roots and base of the trunk. Large clumps of light-brown toadstools come up around the

crowns of badly diseased trees after the first good winter rains. Between the bark and wood of affected parts, a white, felty, fungus growth, *Armillaria mellea,* develops and often causes irregular areas of soft, white decay to appear in the thick bark of the root crowns. Black, cordlike strands of fungus mycelium grow along the surface of the roots. This disease, so destructive to fruit and ornamental trees in California, does not rapidly kill native oak trees growing under natural conditions but most commonly works rather slowly or in a chronic manner on older trees and finally causes them to blow over in heavy storms. Oak trees in gardens or lawns which receive abundant irrigation are more likely to succumb. In cleared land, fruit trees contract this disease in spots where oaks have formerly stood. For further information see page 84.

Powdery Mildew.—In this mildew on deciduous oak trees, the leaves become covered with a typical white, powdery, fungus growth, *Sphaerotheca quercina.* This is scarcely of enough importance to require control.

Rust.—Small fungus pustules of very light-colored rust spores of *Cronartium quercuum* occasionally break out on the undersides of the leaves but are not often abundant. For control see the last section under this tree.

Tip Mildew.—In this disease, the terminal shoots of oak trees, particularly the live oak, *Quercus agrifolia,* become abnormally branched, deformed, stunted, with the leaves reduced to small scales and the whole covered with a dense, white, fungus mildew (*Sphaerotheca lanestris*). These mildewed tips are sometimes abundant all over the tree and greatly disfigure it.

Mildewed shoots should be cut off if one wishes to improve the appearance of the trees. For spraying, see the last section under this tree.

Wood Decay.—Oak trees, on reaching a certain age, are very commonly attacked by heart rot, caused by various fungi. The wood rots out, brackets or toadstools appear on the surface, large limbs break off, trees blow over or split in heavy storms, and many fine specimens become dangerous or unsightly or are entirely destroyed.

The best control in this situation is to prevent the damage or arrest and repair it as early as possible. This can only be done by proper methods of tree surgery. Native oak trees present the highest test of the tree surgeon's art in California. See "Wood Decay" (p. 93).

Control of Diseases of Oaks.—The natural environment in which native California oak trees grow should be kept in mind in trying to maintain them in good condition: the soil beneath them is undisturbed and covered with a blanket of decaying leaves, litter, and the growth of other plants; the soil is wet in winter and dry in summer, with no standing

water in the subsoil during the growing season. If now the ground level is raised or lowered by grading, if the surface mulch is removed each year for the sake of neatness or, worse, if the ground is covered with gravel or pavement or hardened by continual tramping, or if a lawn or garden is planted and the ground kept soaked with water all summer, the trees may decline and die in a very short time.

Assuming that the local conditions which have just been discussed have been handled as well as possible under any given circumstances, at least one good spraying a year may be advisable, combined with thorough cutting out of dead wood and a certain amount of properly done cavity work (see "Wood Decay," p. 93).

Heavy limbs should be properly braced. Oaks are frequently sprayed in early spring with lead arsenate to control the California oak moth, *Phryganidia californica* (see Ext. Cir. 87). In case any of the previously described foliage diseases are troublesome, or for a general cleanup, this spray may be combined with 5–5–50 bordeaux mixture (p. 97) ; 3 pounds of dry lead arsenate may be added to each 100 gallons of spray. Oil emulsion or any other spreader (p. 102) may be added. If mildew is the most serious disease, 6 pounds of wettable sulfur (p. 101) in each 100 gallons of the lead arsenate spray may be used instead of bordeaux mixture. Just before the new growth starts would be the best time for spraying to control fungus diseases. Attacks of tip mildew later in the season may be controlled with the wettable-sulfur spray mentioned above, with or without lead arsenate or any other insecticide which may be in order at the time. If lead arsenate is not needed, a foliage spray composed of 1 gallon of lime-sulfur solution and 6 pounds wettable sulfur to 100 gallons of water is advisable for mildew and other diseases.

OLEANDER

Gall.—Rough, irregular galls or swellings sometimes develop on the woody stems and leaves. This bacterial disease, caused by *Phytomonas Tonelliana,* is very similar to olive knot. Affected branches should be cut off and burned.

PALMS

Bud Rot.—Large, mature trees attacked by this disease may die (fig. 17) from a killing of the terminal bud and rotting of the leafstalk bases. The fungus *Penicillium Vermoeseni*[8] (previously identified as *P. roseum*) is of a type not usually considered an active parasite, but it is constantly associated with this disease. The Mexican fan palm (*Washingtonia ro-*

[8] Identified by D. E. Bliss, Assistant Plant Pathologist in the Citrus Experiment Station. See: Bliss, Donald E. The *Penicillium* disease of ornamental palms. Western Shade Tree Annual Conference Proceedings, vol. 5. (In press.)

busta) is resistant. Palms of *Phoenix canariensis* and *Cocos plumosa* are sometimes seriously damaged along the coast. Affected palms further inland in southern California usually recover.

Affected trees of *Washingtonia filifera* in the coast districts are

Fig. 17.—*Washingtonia filifera* palm trees killed by bud rot.

doomed and should be promptly removed. Replacements may be made with *W. robusta*. Trunk cankers may sometimes be given surgical treatment and the palms saved.

Diamond Scale.—Diamond scale is so called from the elongated, diamond-shaped, black, shiny pustules, ¼ to ¾ inch long (fig. 18) that erupt through the epidermis of leaves and leafstalks. It is caused by the fungus *Sphaerodothis neowashingtoniae.*

Affected leaves should be removed as soon as the disease first appears. The trees may be sprayed with 3–3–50 bordeaux mixture (p. 97), which disfigures the foliage somewhat. A sticker (p. 102) may be added to the spray if it seems necessary.

Leaf Smut.—Leaves of the ornamental date palm, *Phoenix canariensis,* are often disfigured by this fungus disease, caused by *Graphiola phoenicis.* Small, dark, cup-shaped pustules, filled with powdery spores of the fungus appear on mature leaves, which become unsightly and dry

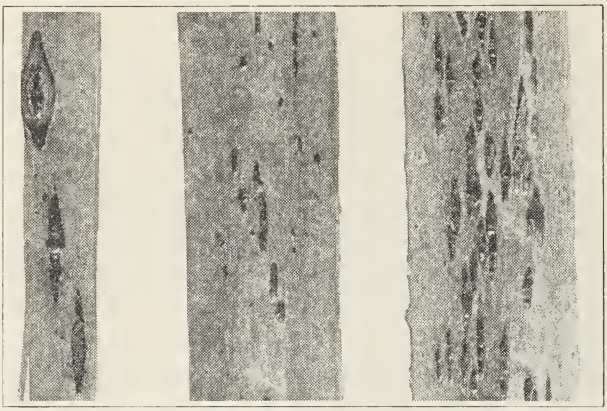

Fig. 18.—Diamond scale of palm.

prematurely. Both ornamental and fruit-bearing dates are affected. Moist atmosphere favors the disease.

Affected leaves should be removed and destroyed. This may be followed by spraying with 3–3–50 bordeaux mixture (p. 97) or, to avoid spray residue, a solution of copper acetate 3 ounces to 50 gallons of water, to which a spreader (p. 102) may be added.

PANSY AND VIOLA

Pansies and violas are not often affected with any serious disease in California. Cottony mold (p. 78) sometimes attacks them, and they are susceptible to fungus leaf spots, powdery mildew and stem rots of minor importance. Curly top (p. 79) is occasionally seen in pansy plants growing near badly diseased beet fields. In this case the plants are stunted and the leaves misshapen. Badly diseased plants should be destroyed. Dusting with sulfur is of general value, especially for mildew.

PEACH, ORNAMENTAL FLOWERING

See also "Prunus, Ornamental and Native"

Leaf Curl.—The leaves when they first come out in spring are sometimes

wrinkled, swollen, and very much deformed. Some years the leaves of the first crop almost all fall off, which greatly disfigures and weakens the trees. The flowering peaches are very susceptible to this disease, which is caused by a fungus, *Taphrina deformans;* but it is easily controlled by proper treatment.

Spray the trees with 5–5–50 bordeaux mixture (p. 97) or lime-sulfur solution 1 gallon to 10 gallons of water (p. 101) just before the buds start to swell. Lime-sulfur helps to clean up scale insects, red spider, and other pests as well as fungi.

PEONY

Botrytis Blight, Bud Blight.—The young flower buds in affected plants die and turn black before opening. Roots, crowns, stems, or leaves may be attacked by a black blighting or rot. Affected parts are covered, especially in wet weather, with a brown, moldy mass of fungus growth, a species of *Botrytis.* All affected parts should be removed and burned.

Crown Rot, Cottony Rot.—In this disease, the shoots wilt and die from a rotting of the crown and roots. A cottony, white fungus, *Sclerotinia sclerotiorum,* is seen on the affected parts and on the soil. See "Cottony Mold" (p. 78).

Leaf Spot.—The leaves may show dead spots or blotches. A number of diseases of this type have been described but none is serious in California. Affected foliage should be removed and burned. Plants may be sprayed with 5–5–50 bordeaux mixture (p. 97).

Mosaic.—Prominent yellow areas appear on the leaves in this virus disease, but the trouble is not a serious one.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Peony plants are susceptible to this fungus. See under "Hollyhock," p. 34.

Root-Knot Nematode.—Plants attacked by this nematode, *Heterodera marioni,* are weak and stunted. The roots are short and stubby and the finer ones covered with small knots or galls.

Plants showing this condition on the roots should not be planted. Soaking dormant roots for 30 minutes in water at 120° Fahrenheit has been reported as killing the nematodes without injuring the plants. Peonies should not be grown in infested soil. See page 82.

Stem Canker, Wilt.—Dead areas or cankers appear on the leaves infected with a species of *Coniothyrium* and cause them to wilt and die. Both ordinary and tree peonies are affected by this fungus. Control is the same as for leaf spot.

PEPPER TREE

Oak-Root-Fungus Disease, Armillaria Root Rot.—Affected trees die, often suddenly, from a rotting of the roots and crown. The characteristic

clusters of light-brown toadstools come up from the ground around the base of the tree, and fan-shaped sheets of the felty, white, mycelium of the fungus are found between the bark and wood. The pepper tree is very susceptible to this disease, and fine, large specimens in parkings and private grounds often succumb to it. From such cases the disease usually spreads to adjacent trees and shrubs of other kinds whose roots are in contact with those of the pepper tree. Affected trees frequently blow over in heavy storms before the tops die.

If the disease is discovered in time, it may be possible to lengthen the life of the tree by surgical work on the roots (p. 87).

Where trees in home grounds or gardens have died from oak root fungus, a serious problem exists in trying to find other satisfactory trees or shrubs for replacement or to treat the soil in any way to eradicate the fungus. It is of no use to plant another pepper tree in infested soil, and most other kinds of trees and woody shrubs are also susceptible. A fig, black walnut, or pecan may be planted with a fair degree of safety, or, if an evergreen tree is preferred, a black acacia or eucalyptus may be suggested.

When the pepper tree is removed, all the roots should be gotten out as thoroughly as possible. Digging a large hole and filling with fresh soil is advisable. Treatment of the soil with carbon disulfide will help to eradicate the fungus but will also kill all living vegetation in the area treated. This is discussed in detail on page 89.

PHLOX

Leaf Spot.—The lower leaves of perennial phlox show dead spots and gradually become withered and die when attacked by the fungus *Septoria divaricata.* To control, clean up and burn all the old leaves and stems very carefully in the fall.

Powdery Mildew.—The leaves affected with powdery mildew show a white growth of the fungus *Erysiphe cichoracearum.* This may be controlled by dusting with sulfur when mildew first appears. The old tops should be carefully cleaned up in the fall.

Root-Knot Nematode.—Phlox plants attacked by this nematode, *Heterodera marioni,* are stunted and have swellings and galls on the roots as on many other hosts. Do not use infected plants or put healthy ones in infested soil. See page 82.

Stem Nematode.—On plants infected with stem nematode, *Ditylenchus dipsaci,* the leaves are narrow and swollen, with wavy edges, and the stems swollen and brittle. This is a strain of the same nematode which attacks alfalfa, bulbs, garlic, and many other plants, but many of the

specialized strains will not attack other hosts. For further details see under "Narcissus" (p. 43) and "Nematodes" (p. 82). The only control is to destroy affected plants.

PHOTINIA, HETEROMELES, OR TOYON

Fire Blight, Blight.—When infected with the fire-blight bacterium, *Erwinia amylovora,* twigs or branches of photinia (Christmas berry),

Fig. 19.—Leaf-miner effect on photinia. The stem injury is often mistaken for a fungus canker.

die with a withering of the leaves as in pear blight. Cutting out may be practiced as in the treatment described for cotoneaster on page 17. Heavy watering should be avoided up to blossom time.

Leaf Blight, Leaf-Miner Effect.—The leaves are sometimes marked with lines and bands of white, scabby tissue. This is caused by very small maggots which feed between the two surfaces of the leaf. The bark of green shoots is also attacked (fig. 19). For control see the last section under this plant.

Leaf Spot.—The foliage of photinia, or Christmas berry, is often disfigured and shabby-looking on account of dead spots on the leaves (fig. 20). *Fabraea maculata* and several other less common species of fungi, and various insects contribute to this effect. *F. maculata* is the cause of a common leaf and fruit spot of the pear in the eastern parts of the country but is not known on this host in California. The fungus may not

Fig. 20.—Leaf spot on photinia.

be identical in the two hosts. For control see the last section under this plant.

Scab.—Small spots of brown, velvety, fungus growth appear on the leaves (fig. 21), flower stalks, and green berries, and disfigure the latter when mature. This fungus, *Fusicladium photinicola,* is very similar to those causing scab on apple, pear, loquat, and other pomaceous hosts, but the ones on different hosts appear to be of different species, so that cross-infection does not occur. For control see the last section under this plant.

Thrips Effect.—A bad stunting, curling, and deformity of the leaves toward the ends of the shoots is caused by minute insects, *Tiothrips ilex,* feeding in the terminal growth. For control see the last section under this plant.

Control of Photinia Troubles.—This popular native shrub often presents a very sorry appearance on account of fungus and insect attacks. Extension Circular 87 recommends spraying with nicotine for pests like miner and thrips. This can be combined with lime-sulfur or bordeaux mixture for fungus diseases. It is suggested that bushes which are in

Fig. 21.—Scab on photinia leaves.

bad condition be thoroughly pruned in winter to remove all dead or weak wood and foliage. They should then be sprayed just before blooming with bordeaux mixture 5–5–50 (p. 97), to which is added ½ pint of 40 per cent nicotine sulfate solution (Black Leaf 40). Lead arsenate may also be added for leaf-eating insects. It is of course not necessary to use the bordeaux mixture if spraying for insects alone.

PINE

Blister Rust.—The presence of this disease in pine trees is usually indicated by a browning of the needles, either on individual branches or on the whole crown. Closer inspection shows the typical cankers which are responsible for the death of the needles. A swelling of the bark appears, either on a branch or on the main trunk. White blisters develop on the surface of these swellings; these rupture and disclose masses of orange-yellow spores. Pitch flows abundantly from the cankers. This fungus,

Cronartium ribicola, attacks only species of the white-pine type, including eastern white pine (*Pinus strobus*), sugar pine (*P. Lambertiana*), and western white pine (*P. monticola*).

Blister rust, like many other rusts, has another, so-called "alternate" form on an entirely different type of host plant, this being certain spe-

Fig. 22.—Gall rust on digger pine.

cies of *Ribes* (see "Currant and Gooseberry, Native," p. 19). The disease cannot pass directly from pine to pine but must first infect *Ribes* from pines and there produce spores to infect other pine trees. The fungus may spread from pine to *Ribes* over distances as great as 150 miles, but from *Ribes* to pine the maximum infection range is only about 300 yards under normal conditions. In new localities, therefore, blister rust is usually found first on currant or gooseberry bushes. After pines are first infected, a period of two to three years elapses before a new crop of spores is produced.

Federal and state authorities are carrying on an extensive campaign to limit the spread of this disease and prevent serious damage to valuable stands of sugar-pine and western-white-pine timber. This is done mainly by eradicating susceptible species of *Ribes,* since the fungus cannot go from pine to pine. Any suspicious symptoms on either host should be

reported at once to the California State Department of Agriculture, Sacramento.

Chlorosis.—When the foliage of pine and other trees is of a bright yellow color and the growth is weak and stunted, the disease called "lime-induced chlorosis" is indicated. This occurs in areas where the soil contains considerable amounts of lime. For further information see page 76.

Western Gall Rust.—This disease is very conspicuous in California on digger pines (*Pinus Sabiniana*) in the foothill regions. On these it causes numerous roundish, good-sized, hard, woody galls or swellings all over the branches (fig. 22). The branch or twig beyond each gall becomes stunted or killed and the tree is greatly disfigured and injured. The much more valuable ponderosa pine is susceptible to this disease but is not seriously affected. Several other species of yellow and scrub pines are also susceptible. The fungus, *Cronartium Harknessii,* is able to infect pine from pine, as well as having an alternate host on species of *Castilleja* and related plants.

This disease is of little importance except occasionally where the digger pine is of some value for ornamental purposes. In such cases, trees with only a few galls may be improved by cutting off all the fungus swellings and removing new ones as soon as they appear. With badly affected trees, it may be impossible to do this without too severe cutting.

PLUM, FLOWERING

See "Prunus, Ornamental and Native" (p. 57)

POINSETTIA

Root Rot, Wilt.—In this disease, the leaves turn yellow and wilt and the plant dies. Examination below ground shows that the fibrous roots are brown and dead. This disease is caused by fungi—*Pythium Debaryanum* and *P. ultimum*—which are greatly favored by overwet soil. Plants may become infected when young but live to make considerable size before collapsing. The poinsettia is a somewhat delicate plant which requires rather special conditions for its successful culture. Overwatering or too low temperature (less than 60° Fahrenheit) while the plants are growing in the greenhouse may predispose them to this disease.

As a precaution against root rot, poinsettias may be rooted in sterilized sand. If this is not done, the grower should at least be careful to use perfectly fresh soil which has never been used for propagating plants of any kind. He should also avoid overwatering and, in the greenhouse, maintain proper temperature at all times.

POPLAR

See "Cottonwood and Poplar" (p. 18)

PRIMULA

Crown Rot, Damping-off.—The fungus *Pythium irregulare* causes the plants to wilt and die from a rotting at the base. It usually occurs in plants which have been overwatered.

Leaf Blight.—Good-sized, roundish, dead spots caused by the fungus *Ramularia primulae* sometimes appear on the leaves. To control, pick off and destroy affected leaves.

Leaf Spot.—Infected leaves show dead spots with conspicuous yellow margins. This is a bacterial disease, due to *Phytomonas primulae.* As with the previous disease, pick off and destroy affected leaves.

PRIVET

Dematophora Root Rot.—The plants sometimes wither and die from a rotting of the roots, caused by the soil fungus *Rosellinia necatrix.* The effect is very similar to that of the next disease. Affected plants, with as much of the roots as possible, should be removed. No information is available as to any resistant hedge plant which may be substituted for privet.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The privet is very susceptible to the omnivorous fungus *Armillaria mellea,* which spreads through the soil and attacks the roots of woody plants of many different species. (See p. 84.) The California wild cherry, *Prunus ilicifolia,* is resistant to the fungus and may be used as a replacement for privet hedges ruined by *Armillaria.*

PRUNUS, ORNAMENTAL AND NATIVE

See also "Peach, Ornamental Flowering" (p. 49)

Black Knot.—Large, elongated, rough, black knots or swellings appear all over the smaller branches, greatly injuring and disfiguring the tree. This is a common disease of plum and cherry in eastern states but in California has only been seen on wild species in the mountains and foothills. It is common in Yosemite Valley on the native choke cherry, *Prunus demissa.* The disease is caused by a fungus, *Dibotryon morbosum.*

Where wild plums or cherries are of any value, all affected branches should be very thoroughly cut out and burned as soon as the knots appear. If this is not sufficient to keep the disease in check, the trees may be sprayed with lime-sulfur 1–12 (p. 101) just as the buds are swelling, if this seems worth while.

Brown Rot.—This fungus disease, caused by *Sclerotinia fructicola* or *S. laxa,* occurs as a blossom and twig blight on *Prunus tomentosa, P. mume,* and other species, and as a fruit rot on *P. cerasifera, P. subcordata,* and *P. ilicifolia.* In the blossom-blight phase of the disease, the blossoms are blasted and withered just as they are opening, and a grayish mold can be seen on the dead parts. Killing of the tissue runs down into the twigs and drops of gum ooze out. In the fruit-rot stage, the

Fig. 23.—Plum pockets on wild plum.

nearly ripe fruit shows a rotting of the flesh with the same mold appearing on the surface. This is a common disease on apricots, peaches, plums, and cherries.

If control of brown rot seems important on these ornamental species, all dead twigs and dried-up fruits on the tree should be removed and burned early in the winter. Then, just as the first blossoms begin to open, the trees should be sprayed with 5–5–50 bordeaux mixture (p. 97).

Plum Pockets.—The fruit in trees affected by plum pockets is swollen, puffy, and deformed (fig. 23), so as to ruin it entirely for eating. This disease is caused by a fungus, *Taphrina pruni,* and is common in cultivated plums in many parts of the world but very rare in California except on *Prunus subcordata,* one of the native wild plums.

Shot-Hole Disease.—*Prunus Davidiana* is very susceptible to a killing of the blossom buds, apparently caused by the fungus *Coryneum Beijerinckii.* In some places the trees rarely bloom on account of this disease.

PYRACANTHA

Fire Blight, Blight.—In this disease, certain twigs or branches die, the blossoms and leaves wither, turn brown, and hang on for the remainder of the season. This is the same bacterial disease as that of pear, apple, and other hosts, caused by *Erwinia amylovora.* See under "Cotoneaster" (p. 17).

As soon as affected branches are discovered, they should be cut off several inches below the infected part and burned. There is considerable difference in the susceptibility of various species of *Pyracantha* to blight: *P. angustifolia* is one of the most susceptible; *P. Koidzumii* is often badly affected; *P. crenulata* is in general moderately susceptible; and *P. coccinea* var. *Lalandii* and *P. Gibbsii* var. *Yunnanensis* are relatively resistant. These species, like those of *Cotoneaster,* vary greatly between individual specimens and must be carefully selected and propagated by cuttings or grafting to insure resistance to blight; by such methods, resistant individuals of almost any type may be secured. Hybrids between *P. angustifolia* and more resistant species are at hand but not yet on the market.

Oak-Root-Fungus Disease, Armillaria Root Rot.—In soil infested with the fungus *Armillaria mellea,* bushes die, often rather suddenly, and a white, felty fungus growth is found between the wood and bark just below the ground. Clusters of tan-colored toadstools may come up around the base of the plant after the first rains (p. 84).

Affected plants should be removed and burned; care should be taken to get all the roots as completely as possible. Removing the soil in a good-sized hole where such plants have stood and replacing with fresh soil will help to delay the progress of this soil fungus. *Pyracantha coccinea* var. *Lalandii* has shown considerable resistance to this disease. *P. angustifolia* is the most susceptible of the commonly planted types.

Root Rot.—See under "Cotoneaster" (p. 17).

Scab.—On pyracantha shrubs affected with scab, velvety, brown, moldy patches appear on berries and leaves, and the growth becomes stunted and deformed. This disease closely resembles scab of pear, photinia, apple, and loquat; it is caused, like pear and apple scab, by a species of *Venturia,* but the exact identity of the fungus in this case is not certain. *Pyracantha coccinea* var. *Lalandii* is commonly attacked.

No treatment to control this disease has been attempted. Spraying with 5–5–50 bordeaux mixture (p. 97) just before blooming time might be effective. Pyracantha species vary somewhat in their susceptibility to this fungus.

QUINCE, JAPANESE

Brown Rot.—Japanese quince, a very early-blooming shrub, is one of the first hosts in the spring to pick up brown rot; the flowers wither and become covered with the rather dense, spore-covered, gray, moldy growth of the fungus *Sclerotinia fructicola* or *S. laxa* (fig. 24). The disease on

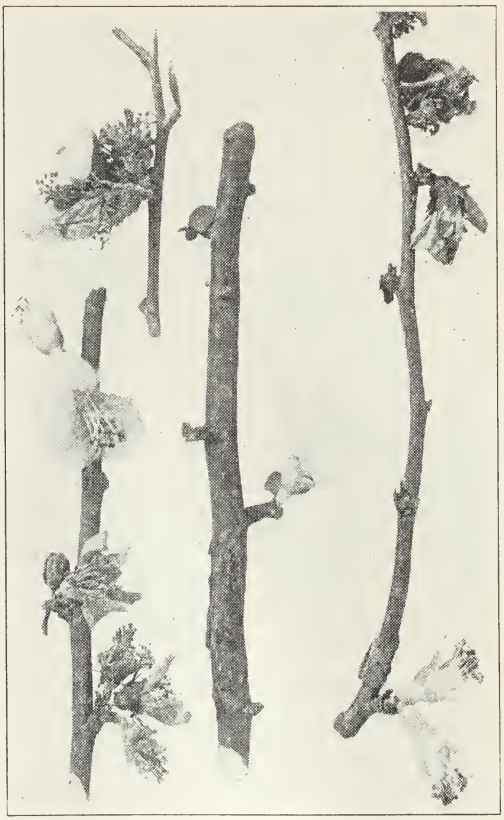

Fig. 24.—Brown-rot blossom blight on Japanese quince.

this host is not an important one in itself, but the Japanese quince should not be allowed to serve as a breeding place for the brown-rot fungus in the vicinity of apricot or peach orchards.

RANUNCULUS

Sclerotium Root Rot.—Ranunculus plants sometimes die from a rotting of the roots, which show rather dry, dead, light-brown areas. From these may be cultured a white, cottony fungus with thin, black, sclerotial

bodies. The fungus is probably a species of *Sclerotium, Botrytis,* or *Sclerotinia* but, since no spores have been observed, has not been definitely determined. Affected plants should be destroyed.

Yellows.—Affected flowers are of a greenish-yellow color and deformed as shown in figure 25. The leaves are yellow and somewhat

Fig. 25.—*A,* Normal ranunculus flower and leaf; *B,* Effect of ranunculus yellows.

stunted and misshapen. The appearance of the diseased plants strongly suggests aster yellows (p. 8). The disease may be due to a virus. It would be wise to destroy affected plants as soon as discovered.

RHODODENDRON[8a]

Leaf Spot.—The leaves, particularly on weak plants, are occasionally disfigured by dead spots, which are usually light-colored with a dark

[8a] For further information on rhododendron diseases see: White, R. P., and C. C. Hamilton. Diseases and insect pests of rhododendron and azalea. N. J. Agr. Exp. Sta. Circ. 350:1–23. 1935.

margin. Small, black dots, the spore pustules of the fungus, *Pestalozzia macrotricha,* are often seen on the surface of the dead portion. Badly affected leaves may fall prematurely. Thrifty plants are not often seriously affected with diseases of this type.

Root Rot.—In this disease, the plant dies from a rotting of the stem just below ground. This fungus disease, caused by a species of *Phytophthora,* usually indicates poor drainage or excess water in the soil, and may be controlled by correcting or avoiding such conditions.

Stunting.—See under "Azalea" (p. 8).

ROSE[9]

Anthracnose.—Circular spots appear on affected leaves, each being composed of a jet-black margin surrounding a light-colored center. Such leaves eventually drop off. The trouble is caused by the fungus *Sphaceloma rosarum.* For control, see the last section under this flower.

Black Spot.—On the upper side of the leaves, dark-brown or black fungus spots, caused by *Diplocarpon rosae* occasionally develop (fig. 26), and increase in size until almost the entire surface is affected. The remaining portion turns yellow and the leaflet falls off. For methods of control, see the last section under this flower.

Blast, Bud Blight, Blossom Blight, Balling.—This trouble affects some varieties more than others. In the unopened buds, the edges of the petals become dead and brown, so that the flowers are unable to expand. Such buds then become shriveled and moldy, usually with the common, gray mold, *Botrytis cinerea,* and drop off without opening. The blasting of the petal edges appears to be due to various causes, sometimes sunburn and at times the feeding of thrips, which become very abundant in the buds. It is doubtful if the *Botrytis* mold is the primary cause. The treatment described in the last section under this flower will help to prevent this trouble.

Canker, Cane Blight, Dieback.—Canker really consists in three separate diseases, brand canker, caused by *Coniothyrium Wernsdorffiae;* stem canker, caused by *C. Fuckelii;* and brown canker, caused by *Diaporthe umbrina.* In all of these, dead areas appear on the canes, especially at wounds, the bark and wood dying back from pruning cuts or flower-stalk stubs. Sometimes whole branches are killed. Control methods are given in the last section under this flower.

Chlorosis.—Chlorotic leaves are yellow or mottled with yellow and green. On soils heavily impregnated with lime, this nonparasitic disease,

[9] For further information on rose diseases see: Waterman, Alma M. Rose diseases: their causes and control. U. S. Dept. Agr. Farmers' Bul. 1547:1–21. 10 figs. Revised 1932.

which affects many other kinds of plants, may affect roses. Plants which show this trouble may be benefited by digging iron sulfate into the soil about them. See page 76.

Crown Gall.—This disease is characterized by rough galls or swellings developing on the roots or at the crown of the rose bush, just as in the same bacterial disease on most kinds of fruit trees and other woody

Fig. 26.—Black spot of rose.

plants. The same organism—*Phytomonas tumefaciens*—is responsible. In the rose it sometimes also happens that similar galls appear on the stems aboveground, usually at nodes or points where injuries have occurred. In some cases in greenhouse roses, large, soft, spongy galls develop in abundance in the stems wherever there has been a cut.

Care should be taken not to plant rose bushes affected with crown gall. Badly diseased plants should be removed and burned. In the case of bushes which are affected in the canes aboveground, it may be possible to cut off the diseased branches and force out new growth if the galls are not too abundant. All cuts, as well as the tools, should be disinfected with 1–1,000 solution of corrosive sublimate (p. 100).

Downy Mildew.—Irregular brown spots are sometimes seen on the younger leaves, with a sparse fungus growth, *Peronospora sparsa,* on the underside. The leaves are blighted and often fall. This disease is not

common or important in California but has been reported in very humid localities or hothouses.

Mosaic.—The leaflets of affected plants growing under greenhouse conditions show distinct yellowish, chlorotic areas, especially along the midribs, and may be puckered or distorted (fig. 27). The blossoms are reduced in number and are often imperfect, pale, and lopsided. The symptoms vary with the variety and with conditions under which the plants are grown. Out-of-door roses, while showing leaf symptoms (fig.

Fig. 27.—Rose mosaic disease.

27) seldom seem to be injured seriously. Ragged Robin, *Manetti, multiflora,* and *Rosa odorata,* commonly used as rootstocks for budding and grafting, are susceptible, and the use of diseased stock is a factor in the perpetuation of the disease; for the virus causing the disease is transferred to healthy plants by buds and grafts.

Several other virus diseases of minor importance have been discovered on roses.

Diseased-appearing plants should not be set in the benches for forcing, and any that are found to be affected should be destroyed. Great care should be taken not to take buds or cuttings from bushes which show this condition. Nurserymen should be certain that their rootstocks are free from mosaic before using them for budding.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Rose bushes sometimes die from the attacks of this well-known disease, especially if they stand near an affected tree of any kind. The characteristic white fungus felt of *Armillaria mellea* is found between the bark and wood, and brown or black, shoestring-like rhizomorphs on the surface of the roots.

Rose bushes affected with oak root fungus should be dug out, and the hole made large enough to remove all roots. In replanting, fresh soil should be used. By this means replants may live for several years even though the disease eventually reappears. See page 84.

Fig. 28.—Rose mildew.

Powdery Mildew.—The young leaves, buds, shoots, and canes of roses often become covered with a white, frosty, or sometimes dense, felty, growth of the fungus *Sphaerotheca pannosa* (fig. 28). This distorts, stunts, and sometimes kills affected parts. Some varieties are much more susceptible than others. For control see the last section under this flower.

Root-Knot Nematode.—The characteristic symptom of this pest is the small, roundish galls or swellings abundantly developed all over the roots, especially on hothouse roses. This causes stunting of the plants. The parasite is the well-known garden nematode, or eelworm, *Heterodera marioni,* which attacks the roots of many other kinds of plants. (See p. 82.)

Affected plants should be destroyed. Greenhouse soil that is infested with this pest must be discarded or steam-sterilized (p. 80). This also applies to benches, cold frames, tools, and other equipment which may

have soil attached to it. No important greenhouse crop is safe in soil which contains garden nematode.

Rust.—In this disease, the leaves become pale and withered and then fall, and on the undersides, the fungus *Phragmidium disciflorum* is seen as an abundance of bright-orange spore dust. Later this turns to dark brown (fig. 29). Certain varieties of roses are much more susceptible to rust than others. For control see the last section under this flower.

Tip Blight, Shoot Wilt.—The tips of fresh young shoots sometimes

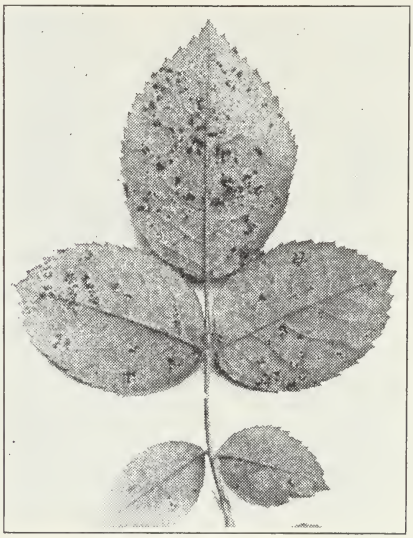

Fig. 29.—Rose rust.

wilt and wither back to a length of several inches. This injury, caused by the raspberry horntail fly, *Hartigia cressoni,* is often mistaken for a disease. Raspberries are also affected. See Extension Circular 87, which recommends cutting off affected shoots as soon as wilting is noticed.

Control of Rose Diseases.—Although the rose is beset by a considerable number of serious diseases and pests, the task of controlling these is not an insurmountable one if it is approached in a systematic manner.

There is a wide range in the susceptibility of different kinds of roses to various diseases. It is not possible, however, to make infallible statements in this matter, applicable to all localities and circumstances. Disease intensity and resistance vary in different times and places and under different conditions, and a variety resistant to one disease may be very susceptible to another. Furthermore, a variety may otherwise have such good qualities that one would rather grow it and fight diseases than sub-

stitute a disease-resistant but less desirable sort. Much can be learned about the variety situation in a neighborhood by visiting other gardens and by looking over large rose nurseries, of which there are many in California. Much information can also be obtained at municipal rose gardens, which are becoming more numerous.

Roses, for best results, should be planted in proper soil and locations, well fertilized, and correctly pruned and irrigated. Information about these matters can be had from Extension Circular 53.[10] In pruning, make all cuts cleanly with a sharp instrument and close to a bud or branch and so leave no stubs or ragged ends to encourage dieback. Dead or sickly wood should be removed. After the winter pruning in December or January, all trimmings and dead leaves should be raked and burned.

The bushes may then be sprayed with a dormant spray of lime-sulfur, 1 gallon to 9 gallons of water (p. 101) (or a scant pint to 1 gallon) or with 5–5–50 bordeaux mixture (p. 97). Lime-sulfur has some value in control of insects as well as diseases. After growth starts in spring, regular applications should be made of lime-sulfur, 1 gallon to 100 gallons of water, to which is added 5 pounds of wettable sulfur (p. 101) and 1 pint of 40 per cent nicotine sulfate solution (Black Leaf 40). For smaller quantities the amounts are 1¼ ounces lime-sulfur solution, 2 ounces wettable sulfur, and 1 teaspoon of nicotine sulfate solution to 1 gallon of water. A light-summer-oil emulsion may be added to the spray as a spreader and sticker, in the quantity recommended by the manufacturer. This may be used every 2 weeks, or more or less often according as diseases and insects appear; and should help to control mildew, rust, black spot, other leaf diseases, cankers, and aphids. If any injury to foliage is caused by the spray, the amount of lime-sulfur should be reduced.

Thorough dusting with dry sulfur, supplemented by nicotine spray or combined with nicotine dust, will more or less accomplish the same purpose, but the wet spray is likely to be more effective. Powdered arsenate of lead for the control of leaf-biting insects may be mixed with the dry sulfur in the proportion of 1 pound to 9 pounds of sulfur.

There are various proprietary mixtures, both wet and dry, which may be used with good results. These often contain sulfur, nicotine, and lead arsenate as the chief ingredients.

For the control of mildew and black spot in the greenhouse, sulfur may be vaporized. To do this, the powdered sulfur is placed in a pan or kettle and evaporated by a low, steady heat, such as by an oil stove, until a heavy vapor fills the house. Great care must be used to keep the sulfur

[10] Butterfield, H. M. Home floriculture in California. California Agr. Ext. Cir. 53: 1–190. 29 figs. Revised 1940.

from taking fire, for the fumes from burning sulfur would ruin the plants. It is advisable, therefore, to place the vessel containing the sulfur on a large pan of sand over the oil stove. Another method consists in painting the heating pipes with a paste composed of equal parts of sulfur and lime mixed with water.

SCABIOSA

Yellows, Aster Yellows.—Scabiosa has been observed to be affected by the California aster yellows, a virus disease (see under "Aster," p. 8), in a few cases.

SHADE TREES

Wood Decay.—See page 93.

SNAPDRAGON

Downy Mildew.—In this disease, the leaves, especially of young seedlings, are spotted and blighted by the fungus *Peronospora antirrhini.* The trouble is favored by poor ventilation and high humidity. Spraying with bordeaux mixture (p. 97) might give some control.

Root Rot.—The plants sometimes wilt and die from a rotting of the main root and lower stem caused by a fungus, *Phytophthora cryptogea.* This disease is usually brought on by poor drainage or excessive watering, which should be avoided.

Rust.—In snapdragon rust, brown, dusty pustules of fungus spores, *Puccinia antirrhini,* develop on the stems and undersides of the leaves, which turn yellow and die, and this ruins the plants.

Varieties of snapdragon are available that are more or less immune or resistant to rust. Seed or plants may be purchased under the designation "rust resistant." In some places a new strain or type of the rust has developed and the varieties which were free from rust are no longer resistant.

On susceptible varieties, dusting the plants with sulfur, beginning before the rust develops, is of considerable value. It is more effective to spray with dilute lime-sulfur solution containing a rosin spreader (p. 102), using 2 gallons of rosin soap and 2 gallons of lime-sulfur with 96 gallons of water. The rosin soap should be added to the water first. In a heated greenhouse it is easier to control this disease by sulfuring than can be done out-of-doors. Keeping the temperature at 75° to 80° Fahrenheit for a few hours after dusting makes the treatment more effective, or sulfur may be volatilized by heat as described for control of rose diseases (p. 67). Removal of rusted plants or picking off rusty leaves as soon as any pustules appear helps to keep down the disease. When buying plants from the nursery, be sure that none are rusted.

Verticillium Wilt, Verticilliosis.—The infected plants wither; this begins rather slowly and in certain branches. The fungus, *Verticillium albo-atrum,* attacks many other plants (see p. 92). Affected plants should be pulled out and destroyed, and snapdragons should not be planted in the same place the following year.

Wilt, Cottony Rot.—Plants affected by wilt die and show a rotting of the stem at the base, caused by a white fungus mold, *Sclerotinia sclerotiorum.* See "Cottony Mold" p. 78). Affected plants and their roots should be destroyed.

Fig. 30.—*A–C,* Effect of mosaic disease of stock on leaves; *D,* normal leaf.

STOCK

Bacterial Blight.—Young seedlings affected with this disease suddenly wilt and collapse. On older plants, large, irregular, elongated, water-soaked areas appear on the stems and branches, usually near the ground or at leaf scars. These lesions or cankers later become sunken and dark brown. The woody tissue is involved to a certain extent. Affected plants wither and die or often break off at stem cankers near the ground. The disease is more common in plants grown during the winter. The or-

ganism responsible for this disease closely resembles *Phytomonas campestris,* the cause of black rot of crucifers, but cross inoculations have not been successful.

This disease has been effectively prevented by immersing the seed in water at 127.4° Fahrenheit (53° Centigrade) for 10 minutes and then

Fig. 31.—*A,* Effect of mosaic disease of stock on flowers; *B,* Normal flower.

drying, just before planting. Stocks should not be planted the following year in soil where this disease has occurred.

Crown Rot, Wilt.—Plants sometimes wilt, wither, and die from a rotting at the base of the stem caused by a fungus, *Phytophthora megasperma.* The disease occurs on plants which have been overwatered, especially on heavy or poorly drained soil. The best preventive is to avoid overwatering.

Foot and Stem Rot.—The root and lower part of the stem of infected plants become black and decayed, and this results in the death of the plant. The fungus that causes this disease is *Corticium vagum,* which attacks many other hosts. Plant stocks in a new place if this or other diseases become serious.

Mosaic.—In diseases of this type the plants are somewhat stunted and the leaves mottled with light-colored streaks and spots (fig. 30). The

Fig. 32.—Effect of mosaic disease on sweet-pea blossoms.

flowers "break" or become mottled and bleached in color (fig. 31), and are thus rendered unfit for the cut-flower market. When grown for seed, the size of the pods is greatly reduced by this virus. Destroy affected plants and spray or dust to destroy aphids, especially in the seedbed.

Verticillium Wilt, Verticilliosis.—In this disease, the leaves droop and the whole plant wilts, lingers a long time, then finally dies. The soil fungus which causes the disease, *Verticillium albo-atrum,* brings about a rotting of the roots and lower stem of stocks and many other plants like snapdragon, crysanthemum, cotton, and tomato (see p. 92). Plants which show wilting should be pulled out and destroyed as soon as detected.

SWEET PEA

Bud Dropping.—In this disease, the flower buds drop before opening. It is favored by excessive watering and nitrogenous fertilizers, which should therefore be avoided.

Mosaic.—The sweet pea is subject to several mosaic diseases. In the one most commonly found in California, called "pea virus," the leaves are mottled with green and yellow or transparent streaks and spots and become much crinkled and deformed. The flower stalks are shortened, the blossoms deformed, and the color breaks—that is, the normal colors are marked with clear, colorless streaks (fig. 32).

Fig. 33.—Spotted wilt of sweet pea causing so-called streak disease.

The disease, caused by a virus, is spread by the pea aphid, *Illinoia pisi.* The spread of mosaic may be delayed by dusting with nicotine to keep down the aphids.

Powdery Mildew.—The leaves and buds become covered with a white, powdery fungus, *Erysiphe polygoni,* which causes stunting of the growth and worthless flowers. To control, dust frequently with dry, powdered sulfur, beginning before mildew develops. This may be combined with nicotine dust for aphids.

Root Rot.—Affected plants have a dwarfed, yellow, sickly appearance and finally die from a rotting of the roots. The disease may be caused by any of three fungi—*Thielaviopsis basicola,* a species of *Pythium,* and *Corticium vagum.* The last fungus named, cause of the so-called "rhizoctonia root rot," attacks many other kinds of plants. No treatment is effective in controlling this disease after it appears. Badly infested soil should not be planted again in sweet peas for several years.

Spotted Wilt. — Reddish-brown, dead streaks develop on the stems (fig. 33) of affected plants and the leaves have roundish spots which are at first yellow, then turn brown. Finally the stems and foliage show a general yellowing and die. This is caused by the same virus as spotted wilt of tomatoes and many other hosts (p. 90) and is spread by thrips. It is probable that much of the disease which has heretofore been identified as bacterial streak is really spotted wilt. In districts near the coast, where sweet peas are mostly grown in California, spotted wilt is of considerable importance. To avoid this disease where it has been troublesome, sweet peas should not be planted near other hosts of spotted wilt (p. 91). Control of thrips may help to prevent the spread of the trouble.

Streak.—Dark-colored streaks develop on the stems (fig. 33) and eventually kill them. The leaves and flowers are similarly affected. The indications are that this disease, which in previous literature has been considered a bacterial infection caused by *Erwinia lathyri,* is in California the virus disease spotted wilt, discussed above.

SYCAMORE

Blight, Canker, Anthracnose.—When the trees start growth in the spring, a fungus known as *Gnomonia veneta* causes a pronounced blighting and killing of the leaves, dieback of twigs, and formation of cankers on the smaller branches. The effect resembles that of a late spring frost. Native sycamores are badly injured in this manner almost every year.

There is no practical control method for this disease on large trees. Valuable specimens planted for ornament might, if not too large, be sprayed with 5–5–50 bordeaux mixture (p. 97) just before the buds start to open. The European sycamore, *Platanus orientalis,* is less susceptible than the native species of California or that of the eastern United States, but is by no means immune to the disease.

Leaf Spot.—In leaf spot, caused by *Stigmina platani,* sooty black fungus spots appear on the undersides of the leaves and sometimes cause defoliation. There is no practical remedy under ordinary circumstances. Spraying as for the last disease might give control if the expense seemed justified.

Powdery Mildew.—In affected trees the terminal leaves are covered with a felty white fungus growth, *Microsphaera alni,* and somewhat deformed. This is most common in wet spring weather.

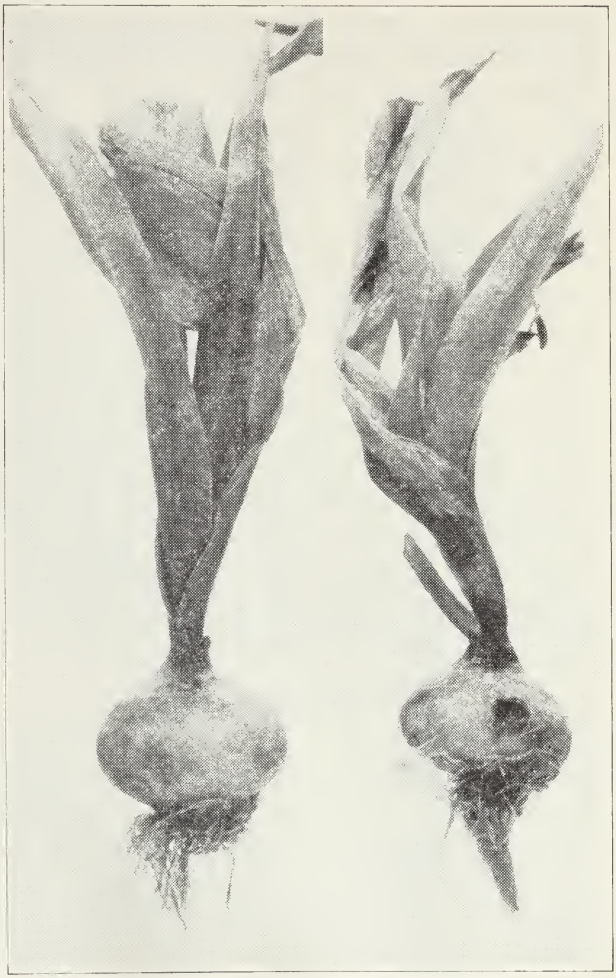

Fig. 34.—Phytophthora root rot of tulip.

TOYON

See "Photinia, Heteromeles, or Toyon" (p. 52)

TULIP

Breaking.—The disease is characterized by a mottling or irregular breaking of the color of the petals. Affected plants are somewhat stunted, and the leaves may also show mottling. The disease is caused by a virus

and spread from plant to plant by aphids. Destroy diseased plants as soon as possible. Spray with nicotine to control aphids.

Fire, Botrytis Blight.—The leaves and petals attacked by *Botrytis cinerea* or *B. tulipae* are affected with a brown decay, which often destroys large areas. Buds are sometimes blighted by the fungus, or the flower stalks may tip over from a spot on the side where the fungus has attacked it; the varieties Kansas, Moonlight, and Zwanenburg are especially susceptible to the latter effect. A brownish-gray, powdery mold is produced on the surface of affected parts. Brown, dead areas are found on the sides of the bulbs and on these may be seen small, black bodies the size of a pinhead. These are the sclerotia or dormant stage of the fungus.

If the disease appears in tulips, all affected parts should be gathered and burned as soon as possible. Badly affected bulbs should be destroyed. Tulips should not be replanted the next year on soil where this disease has been abundant. Plants grown in the greenhouse should be kept well ventilated.

Root Rot.—The leaves of affected plants are crumpled and misshapen and of a light-purple color. The flower fails to develop on account of decay at the base of the stalk. The fibrous roots are destroyed by a watery rot which runs up through the center of the bulb in the flower stalk (fig. 34). The William Pitt variety is particularly susceptible. This fungus disease, caused by a species of *Phytophthora,* is most common in tulips forced in the hothouse for early blooming.

Fresh soil should always be used for forcing flowers of this sort. Affected plants should be destroyed and the soil discarded.

VALERIAN

Leaf Spot.—A fungus, *Ramularia centhrani,* causes dead spots to appear on the leaves, more or less blighting and killing them, but the disease is not important.

VERBENA

Powdery Mildew.—In this common disease the leaves become covered with a dirty gray growth of the fungus *Erysiphe cichoracearum.* Dusting with dry sulfur gives control. There is some difference in the susceptibility of different varieties.

VINCA

Leaf Spot and Canker.—The leaves and stems sometimes show dead spots which may seriously injure the plants. The cause is a fungus, *Phyllosticta vincae-majoris.* To check this, the foliage should be watered as little as possible.

ZINNIA

Curly Top.—The plants attacked by curly top are stunted, with shortened internodes and chlorotic secondary shoots. The flowers are dwarfed, with the petals reduced in number. Natural infection of zinnias with curly top has been seen mostly where the plants grew adjacent to beet fields (p. 79). Under ordinary circumstances the disease is not likely to be observed on this plant.

Powdery Mildew.—The leaves sometimes become covered with a white powdery fungus, *Erysiphe cichoracearum,* which gives them a frosty appearance. The growth is stunted and the foliage blighted. Usually, mildew does not appear on zinnias until late in the season when the crop of flowers is about finished. Dusting with dry sulfur at the first appearance of the disease is the standard remedy for powdery mildews.

Stem Rot, Cottony Rot.—Plants affected with this disease die from a rotting at the base of the stem, and a cottony white mold develops. This is due to *Sclerotinia sclerotiorum,* discussed under "Cottony Mold" (p. 78).

If this trouble develops abundantly on greenhouse plants, it may be necessary to disinfect or change the soil (p. 80) to get rid of the fungus, especially since it has so many other hosts.

Yellows.—The young shoots and leaves of plants infected with this virus disease have a yellowish color and a weak, spindling growth. The flowers are dwarfed and malformed and of a pale color, regardless of the normal hue. This is the same disease as aster yellows, and the infection or virus is spread by the leafhopper *Macrosteles divisus.* The symptoms of yellows and of curly top on zinnias are very much alike.

Affected plants should be removed as soon as detected. Plants may be grown under cheesecloth and protected from leafhoppers.

DISEASES COMMON TO MANY PLANTS

CHLOROSIS

In chlorosis, the leaves become yellow, pale, or nearly white, and the plant is often stunted. "Chlorosis" is a general name for an unhealthy condition of this sort, which may be caused by almost anything that is injurious or unfavorable to the plant. Some of the causes are alkali or other harmful salts in the soil or irrigation water; root injuries by fungi, insects, or rodents; drought or excess water; and lack of certain food materials in the soil. One of the most characteristic types in California is called "lime-induced chlorosis," which is due to an excess of lime in the

soil.[11] In this case, the foliage of trees, shrubs, and other plants in certain soils has a bright-yellow color, the growth is poor, and fruit production scanty. Lime interferes with the absorption and utilization of iron by the plant. If this is the cause of the trouble, it may usually be easily determined by an examination of the soil in which the roots are growing. A simple test for lime may be made by pouring a little muriatic acid or lemon juice onto the soil. If it foams strongly, it probably contains enough lime to cause chlorosis. The lime is often found near the surface, but in some cases it may be necessary to test samples from a depth of 6 feet or more. For a more accurate determination, samples of soil may be taken to a chemist. A lime content of 1 per cent or over is likely to cause chlorosis of certain trees. The pear and lemon are among the most susceptible plants. Acacia, apple, apricot, avocado, cherry, cypress, eucalyptus, grapefruit, orange, peach, pine, plum, prune, raspberry, rose, and many other trees and shrubs are known to show chlorosis in high-lime soils. Strawberries and other herbaceous plants are sometimes affected.

Lime-induced chlorosis can be remedied by the application of iron. There are several different methods of doing this: (1) Ferrous sulfate (copperas) may be spaded or trenched into the soil around the roots, preferably in late winter or spring just before the leaves appear. The quantity may be estimated by allowing 1 pound of iron sulfate to each inch of diameter of the tree trunk. This method is laborious and expensive. (2) Spraying the foliage with a solution of iron sulfate is sometimes practiced; 1 ounce of ferrous sulfate per gallon of water should be used. Spraying should not be done during hot, sunny weather and must be repeated from time to time as new leaves appear. (3) For treatment of woody trees, injection of iron salts through holes in the trunk is usually the most practical method. In applying this treatment, ¼- to 7/16-inch holes are bored in the larger roots, in the trunk above or below ground level, or in branches. The holes should be bored at intervals of 3 to 4 inches around the root, trunk, or branch and from 1 to 3 inches deep. In the bottom of each hole is placed from 1/100 to ⅛ ounce of ground ferrous citrate, and the mouth of the hole is then closed with wax. The number and depth of holes and the dosage varies for trees of different sizes. Anyone intending to apply this treatment should obtain a copy of Circular 321 or write to the College of Agriculture, University of California, Berkeley, for full directions.

[11] For more complete information on this subject see: Bennett, J. P. The treatment of lime-induced chlorosis with iron salts. California Agr. Exp. Sta. Cir. 321:1–12. 1 fig. 1931.

COTTONY MOLD

The fungus *Sclerotinia sclerotiorum* is referred to rather frequently in this circular as the cause of diseases of various plants. In such cases it causes a rotting of stems, roots, leaves, fruit, or other fleshy parts, with an abundant growth of pure-white, cottony, fluffy mold upon the affected

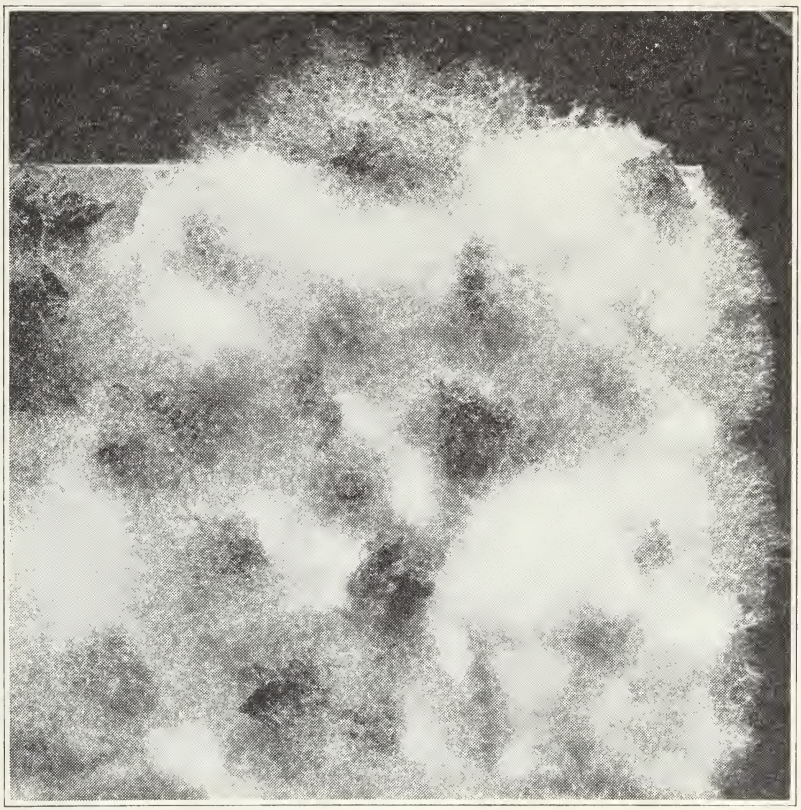

Fig. 35.—Cottony-mold fungus.

tissue (fig. 35). This is a soil fungus which ordinarily grows upon dead vegetable matter, but when moisture is abundant, it may attack living plants, fruits, or vegetables. The fungus forms no spores of any kind upon the white mold, but when there is plenty of moisture, this growth may spread very rapidly. Embedded in it and upon the affected plant parts are seen roundish, black, solid bodies of various sizes up to about ½ inch long and ¼ inch in width or even larger. These bodies are called "sclerotia." During the rainy season, the sclerotia send out little trumpet-shaped, fleshy, toadstoollike bodies with hollow, disk-shaped tops about

⅛ to ¼ inch in diameter on the surface of the ground (fig. 36). These are called "apothecia," and the spores of the fungus are developed in them.

Plants which have a thick mass of vegetation near the ground, or the stems or roots of plants, may become infected with cottony rot by direct contact with the cottony-mold growth; blossoms and fruits and other parts entirely aboveground, which are sometimes attacked, can only become infected by spores developed from sclerotia in the soil and blown about by the wind. The fungus may become very abundant and kill almost any kind of plant in certain spots or areas of soil where there is a

Fig. 36.—Sclerotia (the black bodies) of the cottony-mold fungus developing apothecia (trumpet-shaped, toadstoollike protuberances), in which spores of the fungus are produced at the surface of the ground. (Natural size.)

good deal of moisture and dense vegetation, but it does not always persist long enough to attack other plants growing later in the same places. Sometimes in greenhouses the soil becomes permanently infested with the cottony-rot fungus and must either be changed or disinfected before susceptible plants can be grown again. Treatment with steam or with formaldehyde (see "Damping-off," p. 80) is effective.

CURLY TOP

Curly top, which is best known in connection with the sugar beet and tomato, sometimes attacks a variety of other plants under especially favorable circumstances. Beans, cantaloupes, celery, cucumbers, geraniums (*Pelargonium*), mangels, nasturtiums, pansies, peppers, squash, and zinnias are examples of this. This is a virus disease which is spread from plant to plant by a small insect, the beet leafhopper, *Eutettix tenellus*. (See Extension Circular 87.) In the vicinity of a badly affected beet field, when the beets are ploughed out, swarms of infective leafhoppers spread to all neighboring vegetation, and various kinds of plants may show disease symptoms. These are usually of the nature of stunting, mottling, and deforming of the leaves.

DAMPING-OFF

Young seedlings often rot at or below the surface of the ground, fall over, wilt, and die. The disease starts at spots here and there in the seedbed and spreads through the soil from plant to plant. Typical damping-off is usually seen only in seedlings growing under glass, cloth, or lath covers, where conditions of high soil moisture, high humidity, and high temperature are apt to occur. Such conditions are favorable to the growth of soil fungi like *Pythium, Rhizoctonia, Fusarium,* and others that cause this trouble.

The prevention of damping-off[12] consists in preparing the seedbed so as to keep out these fungi, handling the soil to prevent their development, and treatment to check their spread if they should get started. Seedbeds should be made up of fresh soil and materials which have never before been used for the same purpose. If the bed is on the surface of the ground, it should be well drained and properly leveled to avoid any low spots where the water might stand. The soil should be made of fairly light texture by the use of sand and the top ½ or 1 inch (or less with very fine seeds) may be of pure sand. For growing seedlings in flats, a mixture of ⅓ soil, ⅓ peat moss, and ⅓ sand is recommended.

Soil Disinfection.—In places where there has been much trouble with damping-off, the soil may be treated before planting to kill fungi, as well as nematodes, and possibly insects and weed seeds. All this can be accomplished by treatment with steam.[13] This requires special equipment. Soil disinfection by means of electricity has received considerable attention in recent years and may be of interest to some growers. Details of these methods and references to literature may be obtained by addressing the Division of Plant Pathology, College of Agriculture, Berkeley.

Many different chemical materials have been used to disinfect the soil before planting the seed. Formaldehyde solution is one of the best of these. This kills fungi but does not destroy weed seeds, insects, or nematodes. Use 1 gallon of commercial formalin to 49 gallons of water, applied at the rate of ½ gallon to each square foot of surface. After the solution has been sprinkled over the soil, it should be covered with paper, burlap, cloth, or boards to hold in the fumes. The cover should be removed in a day or two and the soil stirred with a rake as soon as it is dry enough, in order to dissipate the formaldehyde. After this, a period of 8 to 14

[12] For a good account of methods see: Newhall, A. G., Chas. Chupp, and C. E. F. Guterman. Soil treatments for the control of diseases in the greenhouse and the seedbed. New York (Cornell) Ext. Bul. 217:1–56. 23 figs. Revised 1938.

[13] See: Seener, Arthur H. Application of steam in the sterilization of soils. U. S. Dept. Agr. Tech. Bul. 443:1–19. 5 figs. 1934.

days must elapse before it is safe to put in the seed. Soil for flats or pots may be treated in a tight box.

Treatment with acetic acid has given good results in some cases. The details of the treatment are the same as those for formaldehyde, a solution of 1 gallon of glacial acetic acid (almost 100 per cent pure) to 99 gallons of water being used, or a similar preparation of any other strength to make a final solution of 0.8 per cent of the acid. One-half gallon of this should be used to each square foot of soil.

The formaldehyde-dust method consists in mixing 15 pounds of commercial formalin with 85 pounds of some dry, powdered, inert carrier like kaolin, "chalk rock" (infusorial earth), or clay. Lime should not be used. This mixture must be kept in an airtight container or it will rapidly lose its strength. The dust may be thoroughly mixed with soil that is to be used in pots or flats at the rate of 6 ounces of formaldehyde dust to 1 cubic foot of soil. Most kinds of seeds may safely be sown in this soil at once provided it is thoroughly watered. For transplants or cuttings, fully 3 days should elapse. In sandy cutting-bench soil, 3 ounces of dust per cubic foot is sufficient.

Another method is to increase the acidity of the soil while preparing the seedbed by scattering aluminum sulfate over the surface at the rate of 1 ounce per square foot and raking it in to the top inch.

Seed Treatment.—To prevent the development of damping-off, treatment of seed before planting is sometimes practiced with advantage. In most cases the seed is shaken up with a dry, finely powdered chemical so as to cover the surface with the fungicidal substance. Red copper oxide (p. 99) is used for this purpose, also zinc oxide (p. 102) and some of the proprietary mercury dusts (p. 100) are similarly employed. (Manufacturer's directions should be followed.)

Treatment after Planting.—Immediately after the seed is planted, the surface of the soil may be sprinkled with formalin, 1 part to 200 parts of water (1 pint to 25 gallons), 1½ pints of this solution being used to each square foot of soil.

Another method which has been well recommended is to mix ¾ ounce of red copper oxide in 5 gallons of water. As soon as the seed is planted, the bed should be watered thoroughly with this mixture; it should be kept constantly stirred because copper settles quickly. As the seedlings come up through the surface of the ground, they should be watered again with the same mixture and once again when they are about an inch high.

The development of damping-off in seedbeds is largely governed by watering and ventilation. Watering should be done, as far as possible,

in the morning rather than at night; in heavy applications at longer intervals rather than by frequent, light sprinkling; and as little as possible during dull or cloudy weather. Ventilation should be given to the greatest possible extent.

If damping-off starts in the seedbed or flats, it may be checked by keeping the soil as dry as possible, by extra ventilation, and to some extent, by chemical treatment. The plants and soil may be sprinkled with the copper oxide mixture described above, or with 1 pound of copper carbonate stirred into 25 gallons of water, or with 2–2–50 bordeaux mixture (p. 97). Some of the proprietary mercury compounds mentioned above are recommended for this purpose and should be used according to directions on the package. Corrosive sublimate (mercury bichloride) and calomel (mercury chloride) as suggested for the control of brown patch on lawns (p. 38) may also be tried. Dry, powdered zinc oxide may be dusted lightly over the surface.

It may be repeated here that prevention of damping-off is mainly a matter of proper preparation and (if it seems desirable) treatment of the soil or seed before planting, together with subsequent care and skill in watering and ventilation, rather than of treatment with chemicals after the trouble starts.

NEMATODES, OR EELWORMS

Nematodes which attack plants are small worms scarcely visible to the eye which enter or attach themselves to different parts like roots, stems, buds, bulbs, or leaves, and continue their existence there in the living tissue. The presence of these parasites either kills the part affected or causes the development of galls, swellings, and other abnormal growths and eventually weakens or even kills the host plant. These effects are similar to those often produced by fungi and bacteria and, since the causative organism is invisible to the eye, may properly be classed as diseases. Nematodes reproduce by means of eggs which become abundant in diseased plant parts and in infested soil. The eggs average about $\frac{1}{250}$ inch in length and hatch into young worms of a length of about $\frac{1}{32}$ inch (fig. 15, p. 44). These again attack plants when favorable conditions and hosts are available.

The root-knot, or common garden, nematode, *Heterodera marioni*,[14] causes swellings or galls on the roots of a great many different kinds of plants, including most annual crops, fruit trees, ornamentals, and many weeds. The worms are imbedded in these galls, the largest form being

[14] For further information see: Tyler, Jocelyn. The root-knot nematode. California Agr. Exp. Sta. Cir. 330:1–34. 1933. Reprinted 1937.

the adult female, which has a white pearl-shaped body the size of a small pinhead.

The sugar-beet and citrus-attacking species are very similar to the garden nematode; leaf-, bulb-, and stem-attacking nematodes of a number of species occur commonly, especially on alfalfa, begonia, gooseberry, narcissus, strawberry, and other hosts.

Although a great deal of work has been done in many parts of the world in trying to find some way of controlling root-knot nematodes, no practical method has been found except to starve out the worms by growing some unsusceptible crop or keeping the land clear of all vegetation for one or more years. Drying the soil tends to kill out the worms. Of the crops commonly grown in California, the various grains, including corn, sorghum, milo, and kafir, as well as wheat, barley, oats, and rye, are highly resistant and may be grown as winter crops and followed by summer fallow for one or more seasons. The dryer the soil and the more frequently it is worked during the summer, the quicker the worms will be exterminated. Other crops which may be grown are certain varieties of cowpea (consult the Division of Agronomy, College of Agriculture, Davis, regarding names and seed), velvet bean, sweet clover (*Medicago*), and peanuts. *All weeds must be kept down* whenever the eradication of nematodes is being attempted.

Many different chemicals have been tried for treating the soil to destroy nematodes. Newhall[15] lists about fifty different materials which have been experimented with for this purpose. None of them has proved to be of practical value, either on account of poor efficiency, injury to crops, or prohibitive cost. Miss Tyler (see footnote 14, p. 82) discusses this phase of the subject in detail and states that the most promising of these substances are carbon disulfide and chloropicrin. In greenhouse soils these or some other chemical may have some possible value, but effective and practical methods of application have not yet been developed.

The leaf and bud nematode, *Aphelenchoides fragariae,* lives in the fleshy foliage tissue of plants like begonia (p. 9), dahlia (p. 21), gloxinia (p. 33) and others, producing large dead areas in the leaves. The only way of controlling this pest is to discard or disinfect with steam all soil, pots, benches, and other material with which affected plants have been associated. Such diseased plants should be destroyed by burning.

The bulb or stem nematode, *Ditylenchus dipsaci* (see "Narcissus," p. 43, and "Phlox," p. 51), also lives in the tissues of affected plants of many different species. Strawberries, alfalfa, and garlic are among

[15] Newhall, A. G. Control of root-knot nematode in greenhouses. Ohio Agr. Exp. Sta. Bul. 451:1–60. 12 figs. 1930.

these, as well as several floral plants. In this case, however, many of the host-plant species have distinct strains or races of the parasite, so that the worms from narcissus, for instance, will not attack the strawberry, even though they are of the same species. Control of the bulb or stem nematode is discussed under the different hosts.

In greenhouses, nematodes of all types must be handled by destroying affected plants and steam-sterilizing infested soil, pots, beds, benches, and other equipment or replacing with fresh material.

With all crops or plants which are known to be subject to nematode attacks, great care should be taken to guard against introducing these pests into new places. They are usually spread on nursery stock, growing plants, or bulbs, tubers, or other plant parts. All such material should be carefully inspected for nematodes and, if symptoms are found, should be rejected. Nurserymen and florists should be particularly careful in this respect, since nematode infestation is likely to cause them serious losses in rejected stock.

OAK-ROOT-FUNGUS DISEASE

Oak-root-fungus disease, also known as armillaria root rot, is one which attacks and kills many different kinds of plants, especially trees and shrubs. Affected individuals usually show a certain amount of distress before they suddenly collapse and die during dry weather. Sometimes a tree dies suddenly without previous symptoms and at other times it lingers along and makes a certain amount of recovery but finally succumbs. From the behavior of individual trees, it might not be possible to distinguish between this trouble and certain others, such as injury by gophers or certain insects, excess water, or other root rots unless the underground part of the plant is examined. In orchards, hedges, and closely planted areas, the disease usually develops from a center and spreads year after year from one tree or plant to another so that in time extensive areas become killed out. Replacements of susceptible species within the affected area ordinarily die within a few years.

Symptoms.—Trees attacked by oak root fungus, *Armillaria mellea,* when examined at the root, show characteristic symptoms. When an affected root is examined by cutting into the bark, the whole substance is found invaded by white or creamy mycelium in the form of large, conspicuous sheets of fungus growth. In late stages the normal consistency of the root is entirely changed, being first watery and then soft and decaying. The white mycelium is an invariable sign of the disease. It is *never* found in nature on the surface of the root but is always buried within the bark. There is often associated with the white mycelium a gela-

Fig. 37.—The oak-root-fungus disease (armillaria root rot) on an oak tree, showing white mycelium and toadstools.

tinous or gummy material, and in many of the affected trees the margin of the invaded bark gums freely. The odor of this decayed bark is not sour or putrid but a sharp, rather agreeable, mushroom smell.

The fungus also penetrates into the sound wood and causes it to become decayed with a uniform white rotting.

The spores of the oak root fungus are produced on toadstools or mushrooms which are often seen in large clusters about the base of an affected tree (fig. 37). They are usually found in California only in the period from October to February. The toadstools are light-tan color on the top, with tiny brown scales, varying considerably according to the dryness of

Fig. 38.—Rhizomorphs of the oak root fungus on the outside of a root.

the atmosphere. The lower surface (gills) of the toadstool is white or dull white and produces spores, which often appear below the toadstool as a white powder spread over the ground. On the stalk below the top, or cap, of the toadstool is a delicate ring. The spores which make up the powder beneath the toadstools are capable of growing and reproducing the fungus, but apparently there is little danger of infection of living plants by these spores. While they probably become established only in rotting stumps or similar situations, it seems advisable that the toadstools be destroyed to eliminate this possibility of establishing new fungus areas.

Rhizomorphs are dark-brown, cordlike fungus strands which grow out from the infected wood (fig. 38). They often cling to the dead roots or wood in the soil. They may grow for several yards through loose soil, but the length is usually limited, especially in firm soil. They resemble

roots but are smooth and shiny and branch in a different manner. When the tip of the growing rhizomorph, which is white, comes in contact with a susceptible root, it penetrates the surface and spreads out in the bark and cambium into the white fan-shaped sheets of fungus mycelium previously described and causes the rapid death of the invaded part. If conditions are not favorable for their development, rhizomorphs may not form and therefore are not always present.

Susceptible and Resistant Plants.—Nearly all species of trees and shrubs may be attacked. The fungus has also been reported as attacking rhubarb, strawberries, iris, calla, and hollyhock, and sometimes the rhizomorphs penetrate potatoes and cause a rot; but annual or short-lived plants are not often injured. A few kinds of trees and shrubs are resistant, and it is very important that all such be determined as promptly as possible, since in many places there is no feasible way of growing susceptible species on infested land. The French pear root is seldom injured by this fungus. The fig and the various black and hybrid walnuts are considered highly resistant but occasionally die from the disease. The apple, cherry, olive, and citrus roots are more resistant than peach, almond, and apricot, but not enough to help the grower very much. The myrobalan has some resistance, and among its different strains or types there may be some which are very resistant to oak root fungus; nothing of this sort as yet, however, can be positively recommended. The persimmon root is very resistant and also the pecan, as far as experience is available. Of shade and ornamental trees, the following have shown resistance: *Acacia decurrens* var. *mollis, A. verticillata, Prunus ilicifolia, P. Lyoni,* and *Brachychiton populneum* (*Sterculia diversifolia*); also various species of eucalyptus and bamboo. A more extensive list of resistant ornamental trees and shrubs can be obtained from the Division of Plant Pathology, College of Agriculture, Berkeley.

Surgical Treatment.—In some affected trees, surgical treatment may be successful. Usually the disease is not discovered until too late. If the roots of the healthy-looking trees immediately surrounding the armillaria spot, those which in all probability will next become affected, are exposed by removal of the soil, the fungus may be detected as it comes in on those roots. Usually only the roots on the side of the tree adjacent to the spot need be examined. All affected roots or diseased parts should be cut out and removed (fig. 39). In case of large roots that give support to the tree and cannot be removed, the diseased bark may be cut off, the surface painted with a disinfectant, and the root allowed to dry by exposure. All wounds should be treated with some disinfectant. An alcoholic solution of corrosive sublimate (p. 100) has given satisfactory

results and may be made as follows: 1 part corrosive sublimate, 250 parts denatured alcohol, 750 parts distilled or rain water. This solution should not be held in a metal container. If feasible, it is a good plan to allow the roots to remain exposed for a month or more after treatment to dry out thoroughly. This kills the fungus without serious harm to the

Fig. 39.—Surgical work on root of prune tree to arrest progress of oak root fungus. Diseased bark has been removed in the white portion.

tree roots. If this procedure of opening the crowns and exposing the roots is followed each year, the life of the tree may be prolonged for several years and the infested area prevented from increasing in size as it would without such treatment.

Isolation.—Since this parasite spreads through the roots and soil to infest more and more land and kill more and more trees, it is very important to restrict the spread as much as possible and at least hold the fungus within the area already infested. In an orchard it may be advisable to dig out two rows of good trees around the edge of the oak-root-

fungus spot or a solid block may be removed in a badly affected area. Some annual plant may then be grown in the cleared area.

Trenching around the affected area to stop the spread of the fungus has been sometimes recommended. Recent experimentation indicates that this is an unsatisfactory means of controlling the spread unless the trench is left continuously open, and this is seldom feasible. When the ditch is filled with soil, the rhizomorphs rapidly grow through the uncompacted earth and infect healthy roots on the opposite side. Twigs and debris, often mixed with the soil returned to the trench, facilitate the growth of the fungus through the soil by affording it nourishment. Trenching is therefore not recommended as a satisfactory means of control and is to be used only where it can be left open permanently and dug sufficiently deep so that no roots grow under it.

A solid wall or barrier of some kind in the trench has been suggested, but this is seldom practicable. A barrier of galvanized sheet iron has been successfully used in one case to wall off the fungus and may have promise where the cost is not prohibitive. A trench was dug to a depth of about 7 feet and lined on the side opposite the infested area with sheets of galvanized iron having bent interlocking edges. Care must be taken that the barrier is located beyond the infested area and that no rhizomorphs or diseased roots are outside this wall; otherwise it would be useless. The galvanized iron should extend from the bottom of the trench to or above the surface of the ground. To protect the iron against corrosion, it may be painted with hot asphalt or asphalt emulsion.

Soil Disinfection.—Carbon disulfide (p. 101) is effective for killing the fungus in the soil under proper conditions. All living trees and vegetation are killed at the same time, but the fumes soon disperse so that the area can be replanted. It is usually best to take out all trees and shrubs in the affected spot before treatment, and in an orchard this means that at least one and possibly two rows of apparently healthy trees around the edge must be sacrificed to get to the limits of the infestation. If any diseased roots are discovered on such trees, they should be traced back for several feet and removed, and the soil should be treated beyond the point where the last trace of the fungus was found. Care should be taken that roots are not scattered but are collected and thoroughly dried. Blasting is not recommended since pieces of affected roots may be blown to considerable distances and set up new points of infection. In using carbon disulfide, all roots in the first foot of soil should be very carefully removed; below that depth no special care is necessary, after pulling the trees, to get out all the roots in the infested area. In the lighter types of soil, satisfactory results have been obtained by applying 2 ounces by

weight (equals 1⅗ ounces liquid measure) of carbon disulfide in staggered holes in rows 18 inches apart each way. The 2-ounce dose is sufficient to kill the fungus to a depth of 5 or 6 feet, but if many roots penetrate below this depth, a heavier dose will be necessary. The holes should be immediately plugged with soil and tamped. Since this material is heavier than air, it should not be applied at too great a depth, otherwise a satisfactory kill will not be obtained at the surface of the ground. For light sandy soils, the depth of application should be about 8 to 10 inches and in moderately heavy soils not more than 6 to 8 inches.

It is essential that all of the affected area be thoroughly treated if the spread of the fungus is to be stopped. Treatment of the hole made in the removal of a diseased tree is not sufficient. Determining the extent to which the fungus has penetrated the soil or extended on the roots is difficult. Consequently, for safety, the treatment should be extended somewhat beyond the probable limits of fungus penetration even though apparently healthy vegetation must be sacrificed. If the application of carbon disulfide is closer than 6 feet to a healthy tree, there is danger of injury; there is probably danger in going closer than the drip of the branches.

Results to date indicate that spring and summer applications are the most certain to cause a kill of the fungus. The surface of the ground should be moistened to a depth of 4 or 5 inches either before or *immediately* after applying the material to prevent loss of the gas from the surface of the soil. The carbon disulfide may be applied to small areas with a suitable measuring device by emptying it into a hole made with an ordinary bar driven into the ground to the desired depth. Hand devices to inject a measured quantity into the soil are also available on the market at reasonable prices. For the treatment of large areas, power equipment in the form of a subsoiler drawn by a tractor may be purchased or rented.

SPOTTED WILT

Spotted wilt, which is described in this circular under several hosts, represents one of the most serious plant diseases in California. The symptoms vary a great deal on different plants, but the cause of the trouble is the same, since it is readily transmitted from one to another. Over a hundred species of plants have been found to be infected by the spotted-wilt virus, including such crops as celery, tomato, lettuce, pepper, and horse bean; such ornamentals as calla lily, aster, nasturtium, tuberous begonia, gloxinia, cineraria, calceolaria, delphinium, dahlia, petunia, zinnia; and among weeds, nettle, Jimson weed, lactuca, and mallow.

The disease is transmitted by the flower thrips, *Frankliniella californica,* and the onion thrips, *Thrips tabaci.* The larvae of the thrips pick up the virus by feeding on diseased plants and then spread it to healthy ones in the same manner. Symptoms appear in the plant about 2 or 3 weeks after infection occurs. The virus may also be transmitted by rubbing leaves of a healthy plant with juice from a diseased plant, but this type of infection seldom occurs under field conditions.

The disease is most serious in the coastal regions, perhaps because there is no freezing weather to reduce the reservoir of infection in winter crops, ornamentals, and weeds; perhaps because the flower thrips are extremely abundant in those districts. The trouble has been found serious in the interior valleys only where it was introduced on plants grown near the coast, or where there are nearby market gardens where truck crops are grown the year around.

Certain localities apparently function as endemic centers or foci of infection from which there may be considerable spread of the spotted-wilt virus in the spring and summer. These localities are characterized by mild winters, no summer rainfall, and the presence of living host plants throughout the year. Apparently the thrips are active in these centers at all times, but the virus is least abundant just after the winter rains, possibly because of a reduction in the thrips population. Occurrence of the disease in regions remote from foci of infection is often traceable to introduction of the virus with imported transplants. It is not spread through the seed from affected plants. Seedlings from such seed do not develop spotted wilt unless they are inoculated by infective thrips.

In localities where the virus is prevalent, there is less infection in celery, celeriac, peas, endive, and chicory than in tomatoes, peppers, and lettuce. No infection has been observed in onions, rhubarb, beets and sugar beets, chard, globe artichoke, carrots, parsley, beans (*Phaseolus*), crucifers (except ornamentals), or cucurbits. Potatoes, though susceptible, also appear to escape infection.

Besides certain ornamentals and winter crops, certain common winter weeds such as mallow and chickweed may harbor the virus. There is no indication that the virus exists in the native vegetation of uncultivated lands, as does the curly-top virus.

Frequently spotted wilt occurs in the plant beds, and crops set from such beds are sure to be heavily infected. Since the plant beds are usually located near the house and hence near ornamentals and kitchen gardens, infective thrips may readily find their way into the beds.

No effective control for spotted wilt is known. The difficulty of con-

trolling thrips is well known. Spraying with nicotine in the field or plant bed has not been effective. Certain precautions are recommended, however. Spotted wilt is frequently carried over from year to year and from one host to another on affected plants, like nasturtiums (fig. 16, p. 44), which remain alive in a sickly, stunted condition. All disease carriers of this sort should be destroyed. Plant beds should be located as far as possible from kitchen gardens, flower beds, and alfalfa. Alfalfa harbors the flower thrips abundantly during the winter. All weeds should be kept out of the plant beds and the paths and land surrounding them. If old plant beds are to be used again, they should be kept clean-cultivated all summer. Plant beds should be closely watched for spotted wilt, and infected plants should be placed in a cloth sack and removed to a considerable distance from the beds. It is better, if possible, not to use any plants from beds in which infection is occurring, and certainly no plants should be purchased from such beds.

Field roguing of diseased plants may be worth while, at least as long as such plants can be replaced. Before diseased plants are pulled, they should be sprayed with nicotine to kill the thrips. Since plants infected early are worthless, no loss is occasioned by roguing early in the season.

Good resistance to field infection is shown by tomato varieties recently developed from crosses between commercial varieties and the Red Currant type.

In a greenhouse crop, spotted wilt may be controlled by fumigation with nicotine once a week or oftener to kill thrips, and by removing all sources of infection such as weeds, ornamentals, and diseased plants.

VERTICILLIUM WILT, VERTICILLIOSIS[16]

Verticillium wilt is a soil-borne fungus disease of considerable importance throughout California, particularly in the coastal counties. It is caused by *Verticillium albo-atrum*. More than 150 host plants, including stone fruits, bush fruits, truck crops, field crops, ornamentals, and weeds, are known. The disease is contracted through the root system. The woody tissue of the stem is invaded, and the fungus ascends to all parts of the plant. This brings about a wilt in the tops which is identical in most respects with severe drought injury and is often mistaken for it; but, if the wood cylinder be cut into, it will usually be seen to be streaked or stained dark brown. This discoloration has led to the use of the term "blackheart," particularly by apricot growers, as a common name for the disease.

[16] For more complete information see: Rudolph, B. A. Verticillium hadromycosis. Hilgardia, vol. 5, no. 9, p. 197–361. 1931.

Trees sometimes recover from verticilliosis after individual limbs have been killed. Smaller plants and annuals usually die as a result of this disease.

No satisfactory control is known. Spraying is useless, since the parasite attacks exclusively through the root system. Soil disinfectants and amendments have not met the problem satisfactorily. Excessive irrigation should be avoided even though the plants seem to need more water, because the presence of too much moisture in the soil often favors the fungus. When feasible, dead and dying plants should be removed immediately with as much of the root systems as possible. It is not always necessary to remove affected orchard trees, unless they are actually dead, or even to prune out defoliated limbs, because such trees often recover completely the year after the attack. Weeds are susceptible and harbor the fungus. Rotation with susceptible crops should be avoided. In severely infested soil where field crops are grown, immune plants like hay, grain, corn, or other grass crops may be planted for several years to starve out the fungus.

WOOD DECAY[17]

In wood decay, the heartwood of trunk or branches rots and disintegrates, which weakens the tree so that limbs break off or die; resistance to insects, diseases, and injuries is lowered; the life of the tree is shortened; and it is more likely to be tipped over by heavy winds. Decay of this sort is caused in most cases by some of the so-called "bracket fungi," which are closely related to toadstools or mushrooms. Certain insects, like beetle larvae and termites, complete the destruction of the wood. The brackets, or sporophores, that grow out on the surface of affected trees are characteristic of various fungus species (fig. 40) and contain the spores of these organisms. The decaying wood is permeated by the mycelium, or spawn, of the fungus, and it is this which causes the real damage. Most of these fungi are saprophytic or only very weakly parasitic. That is, they live mainly in the heartwood, which is dead, and injure the tree indirectly by gradually wearing down its strength and vitality.

Wood-decay fungi are not able to enter trees through the sound, living bark but usually get in through wounds, pruning cuts, insect injuries, sunburn, fire scars, frost lesions, dead branches, cankers, and

[17] For further information on this subject see:

Collins, J. Franklin. Treatment and care of tree wounds. U. S. Dept. Agr. Farmers' Bul. 1726:1–38. 24 figs. 1934.

Blair, Millard F. Practical tree surgery. 297 p. 89 figs. Christopher Publishing Co., Boston. 1937.

Mulford, Furman Lloyd. Care of ornamental trees and shrubs. U. S. Dept. Agr. Farmers' Bul. 1826:1–80. 1940.

similar openings. Infection is by spores carried by wind, birds, or insects from sporophores on the same or other trees or from dead wood.

Since wood decay usually begins in wounds or dead or weakened tissue, it naturally follows that prevention must lie along the lines of avoiding these conditions as much as possible and protecting such wounds as do occur to prevent infection and promote healing. In or-

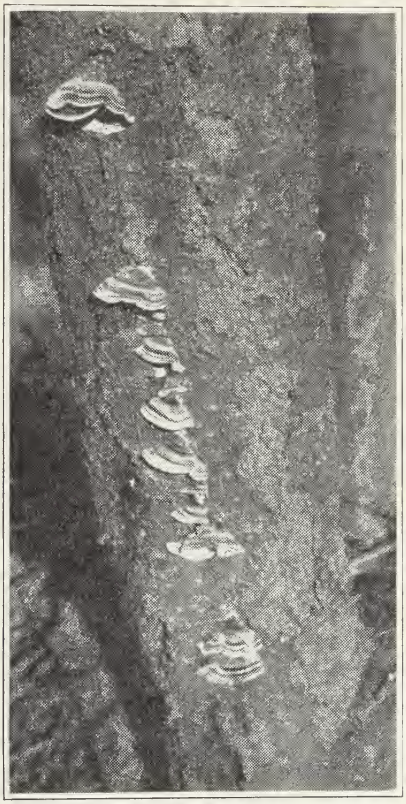

Fig. 40.—Sporophores of a wood-decay fungus.

chard and shade trees, wood decay starts most commonly in pruning cuts, in the stubs of broken-off and dead branches, or in places where the bark has been killed by sunburn and other injuries. Borers are also often responsible for the beginning of wood decay. To prevent this trouble, trees should be shaped up as early as possible to avoid making large cuts. Heavy limbs should be supported by cables or wires. Broken, badly diseased, or dead branches should be cut off. All cuts should be made with sharp tools close to the trunk or supporting limb, and no projecting stubs or torn-down splinters left.

It is possible to accomplish a good deal with trees affected with wood decay by treatment to prevent further progress of the disease and remedy damage already done. In the case of patches of wounded, injured, or diseased bark on the sides of the trunk or large limbs, it is sometimes possible to cut this out, leave the wood exposed, and save the tree or limb if the lesion is not too large, say less than half the circumference. In such cases the affected bark should be cut out with a very sharp tool, making a clean, even edge where sound bark is reached.

All cuts of much size where the wood is exposed should be treated and covered in some manner. The ideal tree paint has not yet been developed, although a great variety of materials has been recommended. The marginal healing of wounds is often more rapid if no dressing at all is applied, but, unless the cut is a very small one, the exposed wood is almost certain to crack and become infected with wood-decay fungi before the wound heals entirely. As a matter of fact, even if the surface is painted, there is scarcely any sort of covering which will remain intact on a good-sized cut long enough to prevent cracking until the wound is entirely healed over, if only one application is made. Whatever dressing is used, the work must be watched from year to year and repainted as often as necessary to keep open cracks from forming. Most of the work which is done to protect wounds is wasted on account of lack of this precaution. On the other hand, if a thick, greasy, moisture-retaining, nondisinfecting covering is put on, it may hold in the moisture and furnish an ideal place for the development of fungi.

The substances most commonly used by professional tree workers are crude creosote and asphaltum, the former as an antiseptic and also as a solvent for the latter, which is used as a covering. Hot, melted asphaltum covers well but is rather troublesome to use, has no antiseptic properties, and sometimes injures the cambium. A water emulsion of asphaltum (Tree Seal, Tree Heal, Pioneer Asphaltum Emulsion) is extensively used for tree work and is satisfactory as far as covering wounds is concerned, but the wood under it often rots. Asphaltum dissolved in crude creosote makes a favorite tree paint, using about ¼ to ½ creosote (by weight). The quickest method of mixing is first to melt the asphaltum and then remove from the fire and stir in the creosote. The latter is very inflammable and should not be exposed near an open flame. Creosote is injurious to some kinds of trees, particularly when it comes into contact with exposed living tissue. The peach, plum, cherry, and prune are especially sensitive to this substance, and one should proceed cautiously in these cases. There is much variation in different grades and types of material found on the market under the name "creosote." Gasoline is

also used for dissolving asphaltum. Another paint is made by melting asphaltum and, before it cools, adding linseed oil and turpentine until the right consistency is obtained. This has no antiseptic effect, however, may run in hot weather, and is sometimes even injurious. Before applying any of these liquid asphaltum mixtures, it is advisable to paint over the cambium and a strip of about ½ inch wide on either side of it with heavy shellac.

Ordinary lead paint may be used for a wound covering and is perhaps as good as anything for small cuts. But it is not antiseptic and some kinds of trees are injured by it.

If any paint which does not disinfect is to be used, the cut may first be treated with corrosive sublimate solution 1–1,000 (p. 100), or copper sulfate (bluestone) 1 ounce to 3 quarts of water. The effect of these substances does not last very long and unless the surface covering is kept intact, they are practically useless.

A paint having disinfecting properties is made by mixing powdered, commercial, "one-package" bordeaux mixture (p. 98) or powdered copper carbonate with raw linseed oil. This makes a good disinfectant and covering, but on large cuts the wood is apt to crack beneath it.

Several commercial tree paints are on the market, such as Sherwin-Williams Pruning Compound. The Bartlett Manufacturing Company of Detroit, Michigan, puts out a black, antiseptic, asphalt-base paint which is well recommended for tree work. The material called "Oronite Roofing Paint" is popular in California for the same purpose.

Whatever paint is used, the main point is to keep the surface covered and the wood disinfected and protected from cracking until the cut or wound is entirely healed over. This result is seldom attained, and it is unfortunate that there is no effective, cheap, one-application material for this purpose.

Sunburn should be prevented as much as possible by keeping the trunks of young trees covered with whitewash. "Outside white" cold-water paint is one of the best and most convenient materials for this purpose. This may be purchased in the form of dry powder to be mixed with water. The same treatment should be applied to trees which have had their tops reduced by top-grafting, frost injury, or any other cause. Trees which have wood decay and dieback resulting from sunburn, weakness, and insect attacks due to drought, poor soil, or neglect, naturally cannot be restored to a sound state as long as these conditions continue.

Cavities already formed in trees by wood decay, if not too far advanced, may in skillful hands, be excavated, treated, and filled in such

a manner as to arrest their progress, permit healing of these wounds, and strengthen the trees to withstand storms. Cement is the material most commonly used for filling although in some cases other materials are used, like rubber, magnesite, or asphaltum mixed with sawdust. Cavity work requires a high degree of skill and experience (not to mention honesty) and should not be attempted by the novice. Much of the work of this sort which has been carried on has done more harm than good. Directions are given in the publications listed on page 93.

FUNGICIDES[18]

COPPER

Bordeaux Mixture.—The following formula, known as the 5–5–50 mixture, is one of the most commonly used.

Copper sulfate (bluestone)	5 pounds
Quicklime	5 pounds
Water	50 gallons

Various other concentrations of bordeaux mixture are recommended for certain purposes, like 8–4–50, 2–2–50, and so forth. The first figure always indicates pounds of copper sulfate, the second, pounds of quicklime, and the third, gallons of water.

The copper sulfate should be dissolved and the lime slaked in separate containers. Copper sulfate dissolves slowly in cold water, especially when the crystals are coarse, but more rapidly in hot water or when in a finely crushed or powdered form. If the material is in coarse crystals, it should be placed in a coarse sack suspended in the top of the water, in a wooden container. Fresh, high-grade quicklime should be used, or the so-called "processed lime," which is pulverized quicklime.

Fresh hydrated lime may be used if no good quicklime is available, but not that which has become air-slaked. If hydrated lime is used, the quantity should be increased by about one-third over that of quicklime.

If large quantities of bordeaux mixture are to be made, it is well to prepare concentrated stock solutions of copper sulfate and lime. A convenient strength of each is 1 pound to 1 gallon of water.

The two ingredients should never be combined in a concentrated form but should be diluted with as much of the water as possible before mixing together. The following method will give good results. Fill the spray tank half full of cold water and start the agitator. Pour in the proper amount of the copper sulfate solution, start the water running, add the

[18] For more complete information see: Robinson, R. H. Sprays, their preparation and use. Oregon Agr. Exp. Sta. Bul. 336:1–30. 1935.

right amount of lime solution through a 20-mesh screen, and fill up with water. If finely pulverized copper sulfate is used, it will dissolve almost instantly in the water and can be poured gradually on to the screen and washed through into the tank without preliminary soaking in another vessel. In preparing smaller quantities of bordeaux mixture, each ingredient may be diluted with half the total quantity of water before mixing.

Commercial Bordeaux Mixtures.—Several commercial brands of bordeaux mixture in a powdered or paste form are on the market. These are more convenient to use than the homemade preparation and usually give satisfactory results, although they are admittedly inferior in sticking and lasting quality to a properly prepared, freshly made mixture. The cost is also greater.

"Two Package" Bordeaux Mixture.—In this commercial preparation, finely powdered bluestone and hydrated lime are put up in proper proportions in separate packages. If the lime is fresh and if both substances are well diluted with water before mixing, this may produce a satisfactory material, but not equal to a freshly and properly prepared homemade mixture. Directions on the packages should be followed.

Oil Bordeaux.—Oil emulsion is sometimes added to bordeaux mixture to improve its spreading, sticking, and penetrating properties. An amount of commercial spray emulsion sufficient to make 1 per cent of actual oil in the final spray is commonly used; this is probably insufficient to increase the adhesiveness of bordeaux mixture materially. It is, however, enough to improve spreading of the spray on plant parts which are difficult to wet. Two per cent or more of actual oil is needed to improve the sticking qualities of bordeaux mixture to any appreciable extent.

Bordeaux Paste.—Bordeaux paste, which is frequently recommended as a wound dressing and antiseptic, is made as follows: dissolve 4 pounds of copper sulfate (bluestone) in 3 gallons of water, slake 6 pounds of quicklime with 3 gallons of water, and mix the two together. Or, mix commercial powdered bordeaux mixture with water to the consistency of a paste.

Copper-Lime Dust.—For the control of certain fungus diseases, the practice of dusting plants with a dry powdered material containing copper finds considerable use. This is prepared by thoroughly mixing together finely pulverized copper sulfate (bluestone) and hydrated lime. Since copper sulfate is a crystalline, gritty, and moist material, it can be pulverized much more effectively by first heating it to drive off part of the water. This causes the crystals to disintegrate and form the so-called "monohydrate." The respective percentages of the two ingredients are

given in expressing the composition of the dust. A 20–80 dust for instance, the usual formula, contains 20 pounds of monohydrate copper sulfate and 80 pounds of hydrated lime. The materials must be fine enough so that 95 per cent of each ingredient will pass through a 200-mesh screen. Better results with copper-lime dust will be obtained if it is applied when plants are wet.

Copper Carbonate.—This is a finely pulverized, light-green powder which is used extensively in seed treatment, especially for cereals. It is also used in some cases as a preventive of damping-off by sprinkling the powder lightly over the surface of the soil and affected plants.

Ammoniacal Copper Carbonate.—When a clear solution which leaves no sediment is required, ammoniacal copper carbonate is occasionally used as a spray instead of bordeaux mixture. It is much less effective as a fungicide. To prepare the spray, mix 7 ounces of copper carbonate into a thin paste with 1 gallon of water. Add slowly to this 3 pints of strong ammonia and stir thoroughly; a clear blue solution is produced. Dilute to make 50 gallons of spray.

Copper Oxide.—Finely pulverized, red oxide of copper (cuprous oxide) has in recent years come into extensive use for seed treatment and is also showing promise as a spray material. Commercial brands are available for these purposes. To be of value, the red oxide must not have deteriorated to the black (cupric) oxide. Superiority is claimed for a yellow, more finely divided form which is now on the market. Powdered graphite is sometimes added to seed being treated with copper oxide to make it run more evenly through a seed drill.

Copper Acetate.—A solution of copper acetate in water has been recommended as a fungicide when a clear solution is desired. Three ounces of the chemical in 50 gallons of water is the strength suggested. This is rarely used and is probably not very effective.

Flordo Spray.—The Florida Agricultural Experiment Station suggests the following formula, especially for treating ornamental plants where a more disfiguring spray is objectionable. This should be tested in a small way before it is used on a large scale or upon valuable plants.

Soap (granular or chip)	10 pounds
Copper sulfate	2½ pounds
Ammonia (26–28 per cent)	1 quart
Water	100 gallons

Dissolve the copper sulfate in 5 gallons of water, add the ammonia to this, stir the soap into another portion of water, and mix all together with the remainder of the water.

Other Copper Sprays.—Many copper fungicides have been developed for the purpose of improving upon or supplanting bordeaux mixture, and a number of these are on the market at present. Some of them have the advantage, for certain purposes, of forming clear solutions which do not disfigure plants as much as bordeaux mixture. It is impossible in a publication of this sort to evaluate fairly these preparations, most of which are new and comparatively untried. It may be said, however, that in the treatment of diseases of fruits, flowers, and ornamentals there is a great need of a good, nonstaining fungicide. There are also cases where bordeaux mixture causes burning or injury to the plant.

FORMALDEHYDE

Formaldehyde, which is a gas at ordinary temperatures, is available in the form of a commercial preparation called "Formalin." This is a solution of formaldehyde in water which is commonly referred to as a 40 per cent solution and should never contain less than 37 per cent for use in the various dilutions recommended for disinfecting purposes. Formaldehyde is used for disinfecting seed, tubers, and bulbs and also for treating soil for destroying parasitic fungi.

MERCURY

Corrosive Sublimate, Mercury Bichloride.—This very poisonous substance is commonly used in plant-disease control as an antiseptic and disinfectant. It is usually dissolved in water, and the concentration is expressed in parts by weight as, for instance 1–1,000. This means 1 gram of corrosive sublimate in 1,000 cubic centimeters (1 liter) of water, or 1 ounce in 1,000 ounces (7¾ gallons). The chemical reacts very strongly with alkaline and metallic substances and so should be used only in wooden, porcelain, or glass containers. Alkaline or "hard" water is unsuitable for preparing this solution; distilled water should be used whenever possible. Corrosive sublimate is also neutralized by dirt and organic matter. Tablets are obtainable of the proper size to make a 1–1,000 solution when 1 tablet is added to a pint of water.

Other Mercury Salts.—Other salts of mercury like mercuric cyanide and calomel (mercurous chloride) are occasionally recommended as disinfectants in plant-disease control work.

Proprietary Mercury Compounds (Semesan, Ceresan).—A number of preparations are on the market which have much value for seed and bulb treatment, soil disinfection, and control of damping-off. These are referred to in a number of places in this circular and are to be used according to directions given by manufacturers.

SULFUR

Dusting Sulfur.—The essential feature of a dusting sulfur for control of powdery mildews and other diseases is extreme fineness. A good brand should be fine enough so that most of the particles pass through a screen of 300 meshes to the inch. There are several types and many brands of dusting sulfur, each claiming peculiar qualities and advantages, but there has been no clear demonstration of any essential factor except the size of the particles. Sulfur causes burning on some plants, especially at high temperatures. Other plants show a toxic effect when treated with sulfur in any form, dry or wet.

Wettable Sulfur.—This is pulverized sulfur to which some substance has been added to make it mix readily with water. Good commercial brands of this material are on the market. Homemade wettable sulfur may be prepared by the following formula:

Calcium caseinate	4 ounces
Water	1 quart
Sulfur (dusting)	2½ pounds
Water to make	50 gallons

Make a smooth paste of the calcium caseinate and 1 quart of water, mix with the sulfur, and add the rest of the water. The same formula may be used with ⅜ ounce of glue dissolved in 3 quarts of water instead of the calcium caseinate paste.

Lime-Sulfur Solution.—Lime-sulfur solution, which is both a fungicide and an insecticide, is a concentrated solution made by cooking together quicklime and sulfur. It was originally a homemade spray made by boiling the ingredients in a kettle, but at present practically all the lime-sulfur in use is bought in the form of commercial brands. The concentration of satisfactory brands is expressed as being usually about 32° or 33° Baumé. Commercial lime-sulfur solution needs only to be diluted with cold water to the proper strength. The various concentrations are expressed either in gallons ("1–100" meaning 1 gallon of a commercial lime-sulfur solution of 32° to 33° Baumé to 100 gallons) or in percentages by volume.

Lime-sulfur solution is a very caustic material and is used either as a winter spray on dormant trees, or on foliage in summer with great dilution and much caution. From 1 to 3 per cent solution (1 to 3 gallons of lime-sulfur solution in 100 gallons of water) is usually the greatest concentration which can be used on foliage.

Carbon Disulfide.—This volatile, inflammable liquid is used as a fumigant against insects and also in the treatment of soil against the oak-root

fungus, *Armillaria mellea*. For the latter purpose pure carbon disulfide should be used and not the water emulsion which is now available.

ZINC

Zinc Oxide.—This is a white powder which is used to some extent for seed treatment and control of damping-off. Commercial brands are available for this purpose.

SPREADERS AND STICKERS

The spreading and sticking qualities of spray materials may be improved by the addition of certain substances. This is particularly important in spraying plants with smooth, shiny leaves which have a strong tendency to shed water. A number of spreaders are on the market, many of them having a base of casein made from milk. Some of the spray-oil emulsions are also used as spreaders. All these commercial spreaders should be used according to manufacturerer's directions.

With lime-sulfur solution, rosin soap gives exceptional sticking qualities on smooth foliage and also seems to improve the effectiveness of the spray. This is made as follows: Melt together with heat the following ingredients, measured by weight.

Rosin (E grade)	25 parts
Potash lye (KOH)	5 parts
Alcohol	1 part
Water	69 parts

In mixing the spray, the rosin soap should be added to the water before the lime-sulfur and should be used in equal volume. Thus, for 2 per cent rosin-lime-sulfur, mix 2 gallons of rosin soap with 96 gallons of water and then add 2 gallons of lime-sulfur.

COMBINATION SPRAYS

It is sometimes convenient and economical to mix two or more sprays together and apply them at one operation. It may happen, for instance, that a fungus disease and an insect both attack a plant at the same time. There may be no one spray material which is capable of destroying both these pests but it is often possible to combine a fungicide with an insecticide and save the cost of one spraying operation. The only objection to such procedure lies in the fact that some sprays cannot be mixed together without producing an undesirable effect or reaction. The result may be a lessening of the efficiency of one or both of the sprays or it may be the formation of some substance which is injurious to the plant. Sprays which react with each other in this way are said to be incompatible.

In Extension Circular 87, a table is given showing which of the common fungicides and insecticides are incompatible. Of the combinations to be guarded against, the following may be mentioned here : Lime-sulfur should not be mixed with standard lead arsenate but may safely be combined with the basic type. Mixtures of sulfur or lime-sulfur with oil sprays should be used with caution, especially in hot weather. Applications of bordeaux mixture or other copper-containing materials should not be followed by fumigation with hydrocyanic acid gas within a year.

New or untested combinations, materials, or methods of preparation should not be used in spraying plants without competent advice or preliminary tests upon a small scale. Even then injury sometimes occurs under certain weather conditions like high temperature or high or low humidity, or only upon certain varieties or species of plants, when ordinarily no trouble is experienced.

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[19] The Plant Disease Reporter. (Mimeo.) Issued by the United States Department of Agriculture, Bureau of Plant Industry, Division of Mycology and Disease Survey.

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